RED STAR VOLUME 30

Soviet Rocket Fighters

Yefim Gordon

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Original translation by Sergey and Dmitriy Komissarov

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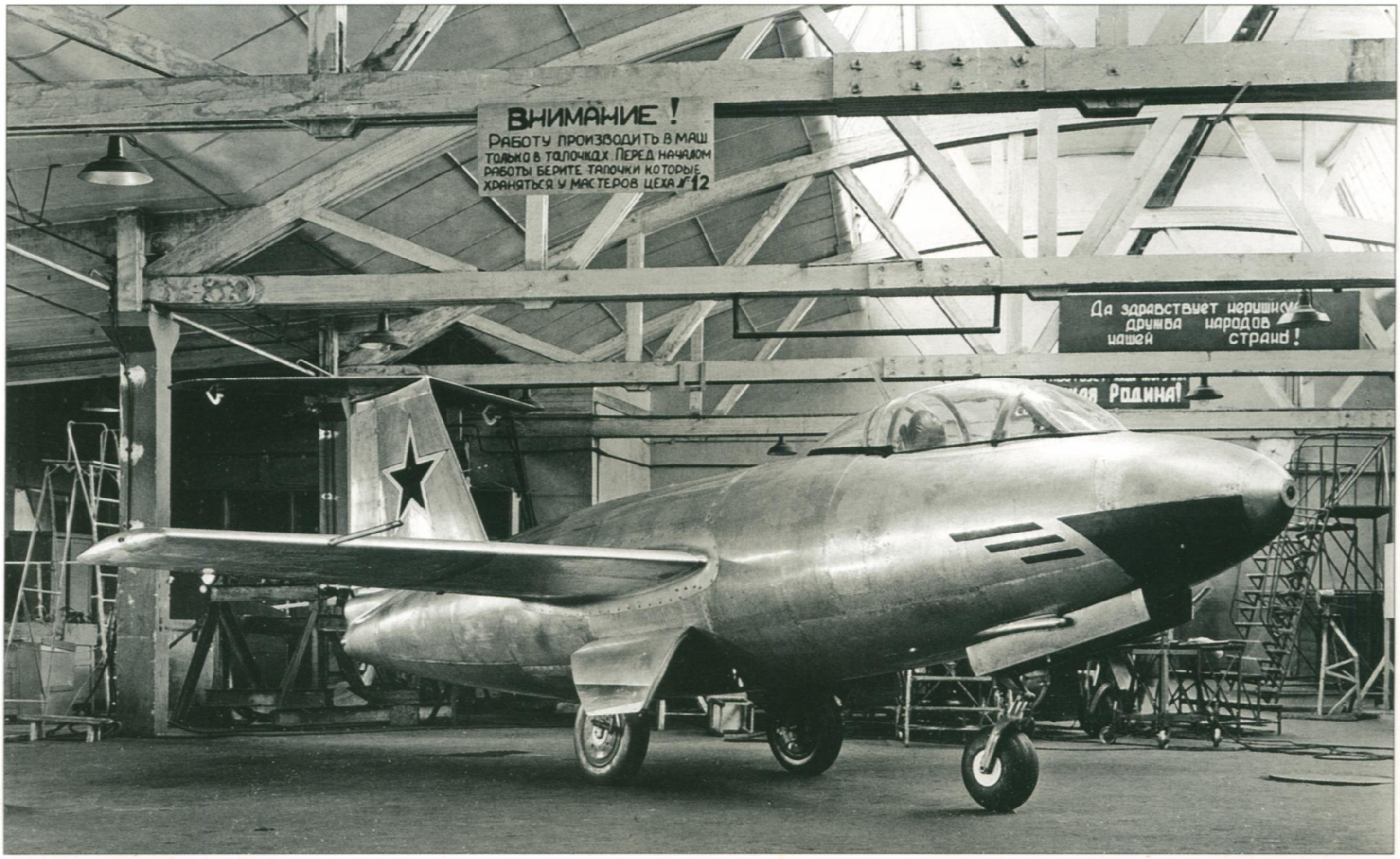
Title page: The Tsybin LL-1 experimental aircraft seen during a ground run of the rocket motor.

This page: The almost complete first prototype Mikoyan I-270 (*izdeliye* Zh) fighter in the assembly shop. The white placard on the rafters reads: 'Attention! Work in the shop to be performed strictly in slippers! Before starting work obtain the slippers kept by the foremen of shop 12.' The slippers in question were presumably needed to avoid getting outside dirt into the work area. The other placards are the usual propaganda stuff: 'Long live such and such'.

Front cover: The ski-equipped third prototype Bereznyak/Isayev BI interceptor (BI-3) begins its take-off run.
Rear cover: This reasonably accurate replica of the BI (made of metal) is on display at the Central Russian Air Force Museum in Monino.


ВНИМАНИЕ !
РАБОТУ ПРОИЗВОДИТЬ В МАШ
ТОЛЬКО В ТАПОЧКАХ. ПЕРЕД НАЧАЛОМ
РАБОТЫ БЕРИТЕ ТАПОЧКИ КОТОРЫЕ
ХРАНЯТЬСЯ У МАСТЕРОВ ЦЕХА № 12
Да здравствует нерушим
дружба народов
нашей страны!
Родина!

Introduction

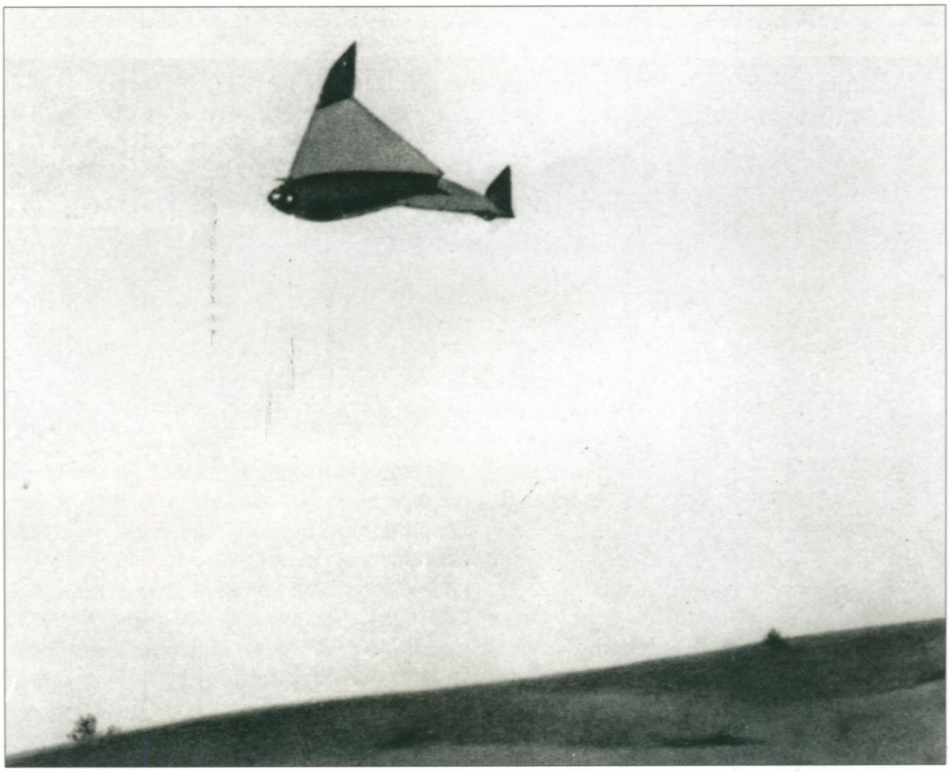
Rocket-propelled aircraft constitute an important part of the history of aviation, rocket propulsion and space technology. Projects of such aircraft figured prominently in the creative activities of the pioneers of rocketry and space technology. The task of designing liquid-fuel rocket motors for such aircraft largely determined the course of development of rocket motor construction in the 1930s and 1940s – the period when the foundations of modern rocketry and space technology were being laid down.

Almost until the end of the 20th century the speed of an aerial vehicle was, for all practical purposes, its most important characteristic. The speed increase was mainly achieved in two ways: by improving the vehicle's aerodynamic shape and by increasing the output of the powerplant. As a result, from year to year the speed of aircraft – especially combat aircraft – steadily increased. However, even an insignificant gain in flight speed required a considerable augmentation of the engine power rating; in the case of piston engines this inevitably led to a growth in the powerplant's overall size and weight. Hence as early as the 1930s the issue of new types of powerplants that would deliver a high power output while keeping the engine's own weight relatively low became increasingly acute. The solution of this problem inevitably brought jet engines onto the scene; work in this field began in several industrially developed countries. Designers of jet engines, as well as aircraft designers, had to spend quite a few years in an effort to gain an understanding of which type of jet engine was the preferable one for a definite type of aircraft.

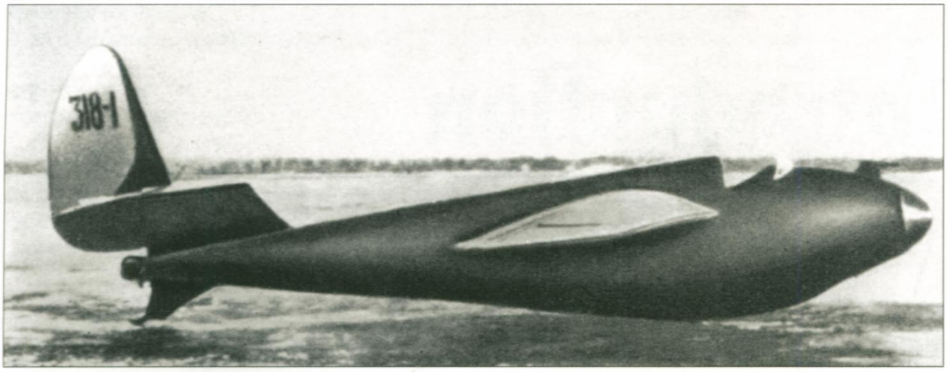
Rocket technology development in the USSR had its inception in the Gas Dynamics Laboratory (GDL – ***Gha****zodina****mich****eskaya laborat****oriya*) and in the Rocket Propulsion Research Institute (RNII – *Ra****ket****nyy na****ooch****no-is****sled****ovatel'skiy insti****toot***), the sole institution of its kind in the world at that time. These organisations were headed by G. E. Langemak and I. T. Kleimyonov. GDL was established in 1921; it was founded by N. I. Tikhomirov, a chemist-engineer who developed the first Soviet rocket projectiles using smokeless gunpowder. The Soviet pioneers of rocket propulsion technology received much practical help from Marshal Mikhail Tukhachevskiy, the then Deputy People's Commissar of Defence. In 1932 he signed an order calling for the establishment of the RNII. Subsequently, during the period of reprisals instigated by Iosif V. Stalin, Tukhachevskiy was arrested and executed; the same fate befell Langemak and Kleimyonov.

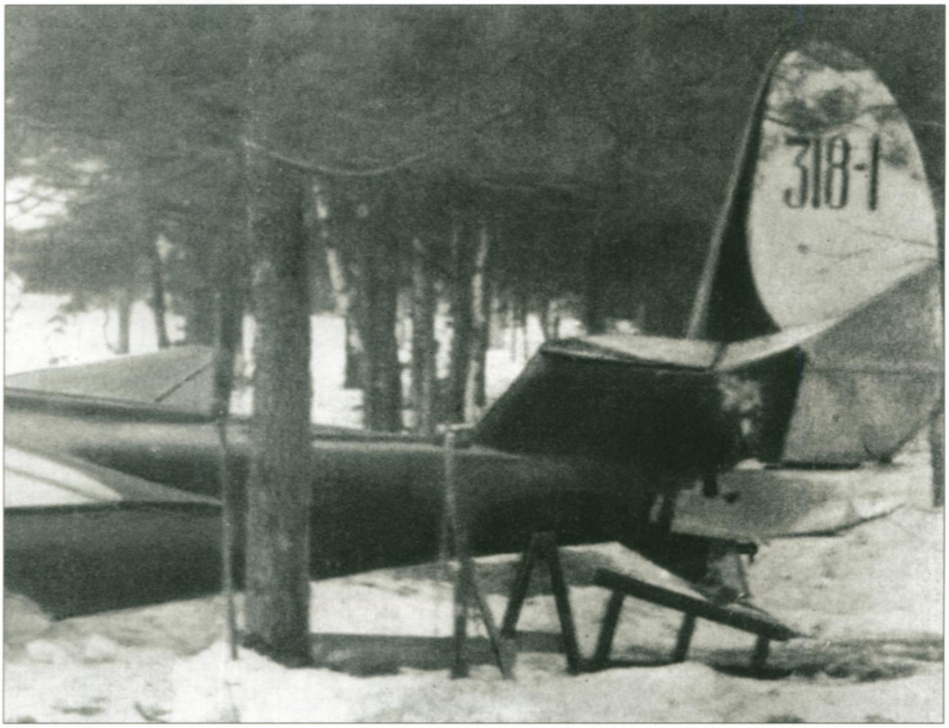
One of the first attempts in the Soviet Union to make use of jet propulsion on an aircraft was made by Sergey Pavlovich Korolyov who later became a renowned designer in the field of rocketry. He dreamed of converting the SK-4 lightplane of his own design into a rocket-propelled aircraft. However, on such an aircraft the rocket motor had to be accommodated in the aft fuselage, which entailed shifting the CG rearward and making the aircraft tail-heavy. In this connection attempts were made to install the OR-1 and OR-2 rocket motor designed by Felix A. Tsander on other types of aircraft; initially gliders were considered for this purpose, and a still better proposition seemed to be the use of a tailless aircraft because in this case the CG shift would be reduced to a minimum. To begin

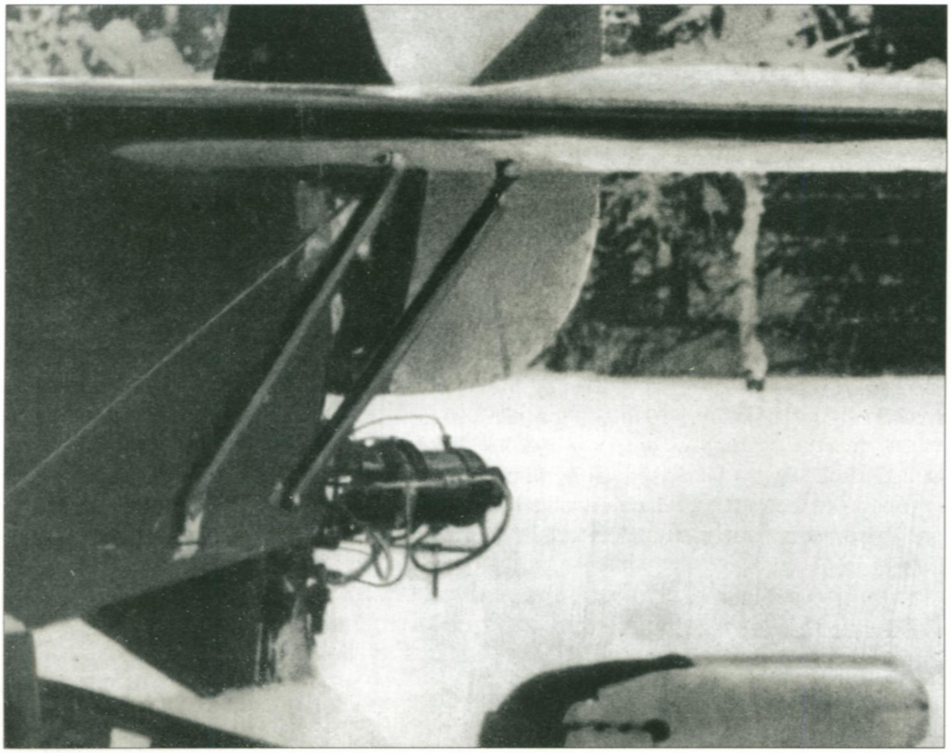
Above: Best known for his successes in designing missiles and space launch vehicles, Sergey P. Korolyov also created several light aircraft, including rocket-propelled ones.



The unusual Korolyov RP-1 rocket-propelled glider (a powered version of the Cheranovskiy BICh-11) displays its 'flying wing' design with wingtip-mounted vertical tails.







with, the BICh-8 glider designed by Boris I. Cheranovskiy was chosen; then a decision was taken to design a tailless glider designated BICh-11. This was a single-seat machine of wooden construction featuring delta wings and wingtip-mounted vertical tails (the 'flying wing' layout). When fitted with the OR-2 rocket motor, the BICh-11 was redesignated RP-1 (*ra**ket**nyy* ***plah**ner* – rocket-powered glider). However, the very first tests undertaken with the RP-1 in 1932 showed that there was still a long way to go to a true rocket-powered aircraft.

In the late 1930s, experiments were started in the Soviet Union with the installation of two additional ramjet booster engines designed by I. A. Merkulov on Nikolay N. Polikarpov's I-15*bis* and I-153 biplane fighters. However, they afforded a speed increase of a mere 15 km/h (9.3 mph), which was clearly insufficient.

In the spring of 1940 the leaders of the main Soviet aircraft design bureaux were invited to a meeting, in the course of which they were informed about prospective new powerplants incorporating various types of jet engines – mainly liquid-propellant rocket motors and ramjets. On 12th July 1940 the Defence Committee under the Council of People's Commissars of the USSR adopted a directive calling for the development of the first Soviet jet-powered aircraft. The directive envisaged, among other things, the solution of issues pertaining to *'the use of high-power jet engines for stratospheric flights at super-high speeds…'*.

The fundamental feasibility of creating liquid-fuel rocket motors intended for aircraft was studied in the USSR in the works of Valentin P. Glushko, M. K. Tikhonravov and other Soviet scientists and designers in the early 1930s. Sergey P. Korolyov and Ye. S. Shchetinkov undertook studies in the engineering design related to the use of these engines on aircraft and to design features of the aircraft so powered. However, developing liquid-propellant rocket motors to a degree enabling them to be installed in an aircraft involved solving a whole range of difficult tasks. The first models of liquid-fuel rocket motors, still far from perfection yet suitable for installation in an aircraft, were developed in the USSR by RNII and in Germany by the

Top left: The RP-318 rocket-propelled glider designed b y Sergey P. Korolyov. The rudder is marked '318-1', denoting the first prototype.

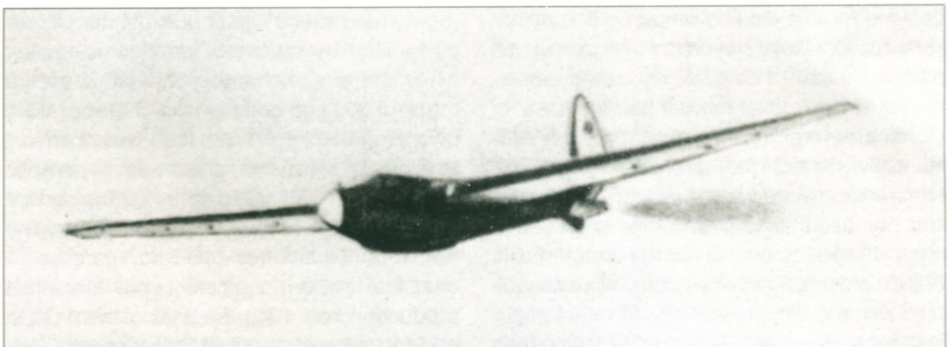
Above left: The RP-318 with the tail trestled for engine runs. Note the all-movable vertical tail, the high-set horizontal tail and the fairing/heat shield over the rocket motor to protect the rudder from burning up.

Left: The RP-318 with the tail fairing removed, exposing the ORM-65 rocket motor.

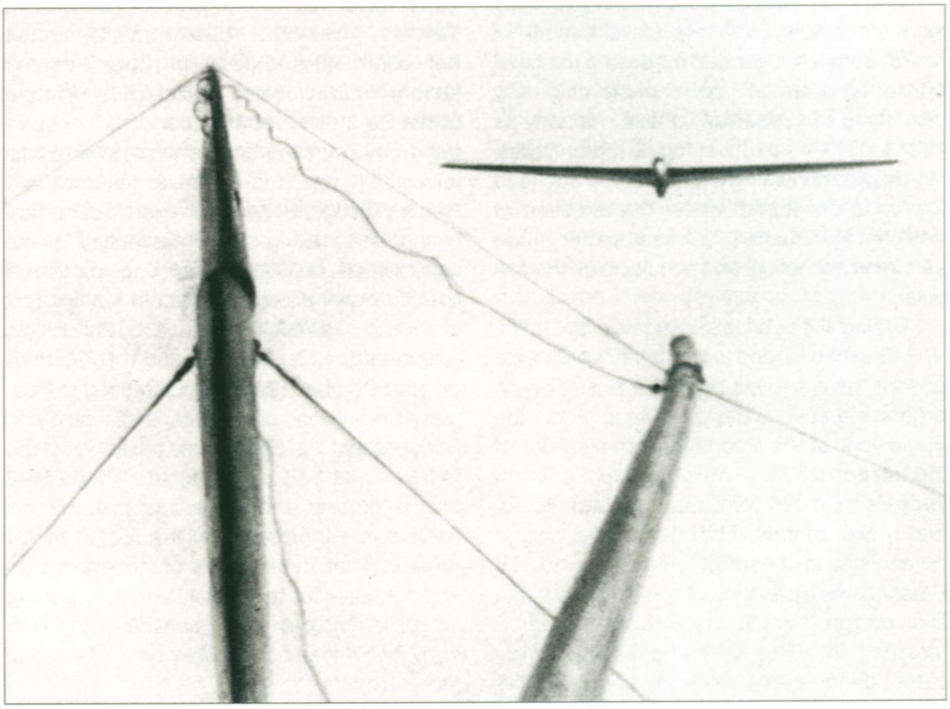
Walter company in the late 1930s. The emergence of these engines was of paramount importance. Both in the USSR and in Germany initial work on the subject was based on the use of existing gliders and piston-engined aircraft. Aircraft designed around liquid-fuel rocket motors from the outset were developed and started entering flight test in 1939-1942, when the focus of attention was turned to a more pragmatic and urgent task of that time – the development of rocket-powered combat aircraft for various missions.

The Second World War saw a dramatic increase in the impetus given to work on rocket-powered aircraft. Within that relatively short space of time numerous projects emerged of the aircraft in question, some of them reaching the hardware stage. During the Great Patriotic War Soviet specialists turned their attention primarily to the development of rocket-powered interceptors. In so doing, they tried to curtail as much as possible the stage related to creating experimental machines, guided by the wish to develop a combat aircraft that would immediately be suitable for operational use at the fronts.

It was the aforementioned Sergey P. Korolyov who was the first to suggest the idea of developing such a fighter as early as 1938, when he was engaged in designing his RP-318 rocket-powered aircraft. He surmised that a liquid-fuel rocket motor with its inordinately high specific fuel consumption (4-6 kg/8.82-23.23 lb of fuel per second for a thrust of 1,000-1,500 kgp/2,205-3,310 lbst) could most effectively be used on an air defence interceptor which would take off from quick-reaction alert mode at an airfield immediately after the visual spotting of enemy aircraft in the vicinity of the protected objective. The liquid-fuel motor, with its low weight and high thrust rating, was expected to give the rocket-powered interceptor a maximum speed in level flight as high as 800-850 km/h (497-528 mph). Most importantly, such an interceptor would have a rate of climb truly enormous for that period – nearly ten times that of the best piston-engined fighters. Thanks to the high speed and rate of climb in the active phase of its flight with the rocket motor running, the rocket-powered interceptor would be able to catch up with the enemy aircraft quickly, attack it right away and destroy it with cannon fire. When the engine cut after using up the fuel, the interceptor was to break off the attack and perform a landing in glider mode; this was not expected to pose a problem, bearing in mind the considerably reduced all-up weight after the fuel tanks ran dry and the ammunition was used up. The short endurance was, in Korolyov's opinion, the main weakness of such an aircraft. Military specialists gave Korolyov's proposal a positive appraisal and emphasised in their conclusions that operational use of such aircraft was feasible, despite the short endurance.



Above: The RP-318 in flight with the rocket motor running.
Below: The RP-318 glides to a landing after using up the rocket propellant.



Indeed, getting somewhat ahead of our story, we may state that by the mid-1940s, when the Second World War was in full swing, the maximum speed of the best fighters was just approaching 700 km/h (435 mph). Coming even closer to the speed of sound led to a sharp increase of drag; at the same time the engine power required for attaining a speed increase was no longer proportionate to the squared value of the speed and grew at a faster rate. On the other hand, beyond the threshold of 750 km/h (466 mph) the efficiency ratio of a propeller dropped sharply due to the blade tips' linear speed approaching the speed of sound, which engendered shock-wave drag that ate up a considerable part of the engine power output. Thus, the need for powerplants of a new type manifested itself with increasing acuteness.

Further tests of ramjet engines in the role of jet boosters conducted in the USSR on the Lavochkin/Gorbunov/Goodkov LaGG-3 and Yakovlev Yak-7B fighters confirmed that a moderate increase of speed was accompanied by a marked deterioration of some other performance characteristics. Besides, the ramjet engines could function only when a sufficient dynamic pressure of the slipstream was available; in other words, this engine type could not be used for accelerating the aircraft on the airfield. That meant it could not be employed as the main powerplant.

On the other hand, the idea of using liquid-fuel rocket motors as powerplants for fighters looked more promising; at that time such engines were under development at the design teams headed by Valentin P. Glushko, Aleksey M. Isayev and Leonid S. Dooshkin. As distinct from ramjets, which were usually fitted under the wings of a fighter and thus created substantial drag, the liquid-fuel rocket motors were easily accommodated within the contours of a fighter's fuselage. In addition, as distinct from an engine driving a propeller, the thrust of the liquid-fuel rocket motor did not depend on the flight speed. Therefore, even as the war raged on, flight testing was started in the USSR of the BI rocket-propelled fighter designed in the Bolkhovitinov OKB (***op***_ytno-kon_***strook***_torskoye byu_***ro*** – experimental design bureau). However, as stated earlier, the liquid-fuel rocket motors had the 'vice' of inordinately high fuel consumption that substantially limited the aircraft's range and endurance. Moreover, the corrosive substances used as the propellants posed a great danger, above all for the aircraft itself. The greatest technical problems were associated with the design and development of aircraft rocket motors. The main task facing their designers was to ensure reliability and the necessary engine life.

One of the important aspects of jet propulsion technology was the development of rocket boosters intended for easing the take-off of heavy aircraft and capable of greatly increasing the speed of fighters. As early as 1941 the RD-1 liquid-fuel rocket motor (***raket***_nyy_ ***dvig***_atel'_) yielding a thrust of 300 kgp (660 lbst) was developed under the direction of Valentin P. Glushko. It used tractor-grade kerosene as the fuel and nitric acid as the oxidiser.

During the reprisals instigated by Stalin, V. P. Glushko landed in the notorious Butyrka prison; there he was offered a possibility to organise a special design bureau within the framework of the People's Commissariat of the interior (NKVD – _Na_***rod***_nyy komissari_***aht*** ***vnoot***_rennikh del_) for development of liquid-fuel rocket motors. The staff of the design bureau was to consist of specialists who, like Glushko, were prisoners. From 1939 onwards this design bureau had its premises in Moscow. In 1940, when the German army came dangerously close to Moscow, the group moved to the Kazan'-based engine plant No.27, where it got to grips with the design of single-, twin-, three- and four-chamber aircraft rocket motors with pumps for fuel feed; these motors delivered a thrust of 300 to 1,200 kgp (660 to 2,650 lbst) at sea level. Although the design bureau operated at the premises of plant No.27, it was subordinated directly to an NKVD security officer, V. P. Beletov, who had an engineer's education. Together with Glushko's group engaged in the development of liquid-fuel rocket motors, a group led by V. S. Stechkin worked on straight-flow pulse-jet engines. In 1942 an example of the RD-1 engine passed bench trials which included 25 firings with an overall duration of 1 hour and 10 minutes without requiring removal from the bench. The maximum duration of uninterrupted functioning of the engine reached 40 minutes. Bench tests were in the charge of Glushko's deputy, D. D. Sevrook. In addition to testing, Sevrook was engaged in the design of automatic devices for controlling the engine tests.

The RD-1 single-chamber rocket motor rated at 300 kgp and the RD-3 three-chamber motor rated at 900 kgp (1,980 lbst) had ether-air ignition by means of an electric igniter, while the single-chamber RD-1KhZ with a thrust of 300 kgp and the twin-chamber RD-2 delivering 600 kgp (1,320 lbst) had chemical ignition by means of a start-up hypergolic (self-igniting) fluid called carbinol. The service life before the first overhaul was 1 hour. The RD-1KhZ (_khi_***mich***_eskoye zazhi_***gah***_niye_ – chemical ignition) engine was put into series production from 1945. Engines of this type, in addition to bench test and development trials, passed ground and flight tests (nearly 400 firings) on the Petlyakov Pe-2R, Lavochkin La-7R and La-120R, Sukhoi Su-7 and Yakovlev Yak-3RD development aircraft between 1943 and 1946. In Kazan', aircraft factory No.22 allocated a production example of the Pe-2 dive bomber (construction number 15/185) for the engine tests; later it was joined by one more similar aircraft (c/n 11/189). Sergey P. Korolyov exercised control of the tests, taking part in test flights in the capacity of test engineer. The prototype machine was piloted by Kazan' factory test pilots A. G. Vasil'chenko and A. S. Pal'chikov. A report signed by Korolyov and V. P. Glushko on 15th October 1943 and addressed to People's Commissar of the Interior Lavrentiy P. Beriya stated that by that time ten firings of the rocket motor had been effected on the Pe-2 on the ground and eight successful flights had been performed with the rocket motor running. That, in the words of the report, provided a basis for the conclusion that *'putting rocket technology at the service of the Red Army within the shortest time possible'* was a realistic matter.

Nevertheless, the testing of the RD-1 was accompanied by incidents of a varying degree of gravity. More than once the rocket motor installation exploded in flight when a mixture of fuel and oxidiser ignited due to leaks in the piping. Thanks to the bravery and high skill of the test pilots all these incidents ended without all-too-serious consequences. Here it should be noted that on a twin-engined aircraft the consequences of such accidents were, after all, less ruinous than on a single-engined fighter. The case in point is the fate of V. L. Rastorgooyev, a prominent Soviet test pilot who was killed when testing Valentin P. Glushko's RD-1KhZ rocket booster installed in the Yak-3RD experimental fighter.

Manufacture of rocket boosters at plant No.27 continued up to January 1946. At that time there was no production of turbojet engines in the USSR, and, should an enemy resort to large-scale use of turbojet-powered aircraft, Soviet aviation would be in a pitiful situation indeed. According to the concept nurtured by the nation's leaders, the installation of rocket boosters on fighters and bombers would make it possible to improve their speed characteristics to some extent. During the year of 1945 alone, the plant turned out 180 RD-1 engines, of which 41 were accepted by the Military Representative on site and a further 59 passed delivery check-up tests.

Getting somewhat ahead of our story, we should mention that on 18th August 1946 the '120R' fighter designed by Semyon A. Lavochkin's OKB-301 made a flypast with the rocket booster running during the annual air event at Moscow's Tushino airfield. During testing this fighter attained a speed of 805 km/h (500 mph).

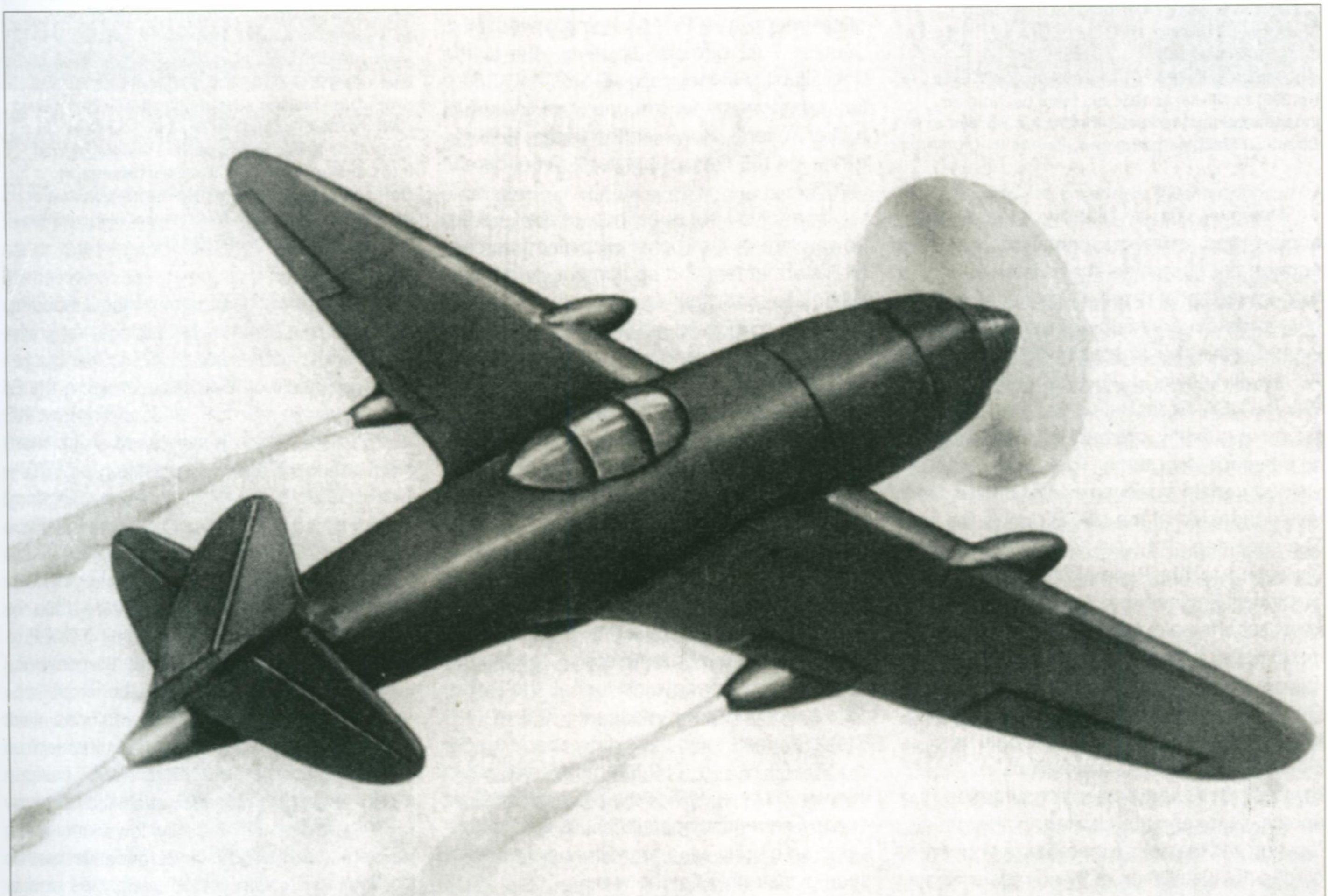
Coming back to rocket motors, it should be noted that during the war the greatest success in this field was presumably scored by the OKB led by L. S. Dooshkin which developed the most powerful liquid-fuel rocket motors. In 1942 it produced the D-1A-1100 with a thrust rating of 1,100 kgp (2,425 lbst) for the BI interceptor, followed in 1944 by the RD-2M engine delivering 1,400 kgp (3,090 lbst) for the '302' aircraft. These rocket motors could already be used not merely as boosters but as aircraft powerplants in their own right. However, their reliability, too, left much to be desired. Aleksey M. Isayev modernised the D-1A-1100 rocket motor and extended its time between overhauls (TBO) to 1 hour. Redesignated RD-1M, it successfully passed state acceptance trials in 1945. V. P. Glushko developed the RD-1 liquid-fuel rocket booster with a thrust of 300 kgp for the Yak-3 and La-7 piston-engined fighters, and intended to develop three- and four-chamber rocket motors with a thrust rating of 900 kg and 1,200 kgp (1,980 and 2,650 lbst) respectively on its basis. However, these plans did not materialise because the OKB headed by Glushko was reassigned for work on other tasks.

In the meantime L. S. Dooshkin at NII-1 subordinated to the People's Commissariat of Aircraft Industry (NKAP – _Na_***rod***_nyy komissari_***aht*** _aviatsi_***on***_noy pro_***mysh***_lennosti_) developed a new powerful twin-chamber liquid-fuel rocket motor. Designated RD-2M3V, it featured a delivery pump and used kerosene and nitric acid as the propellants. The engine had unequal chambers: a bigger one with a thrust of 1,100 kgp (2,425 lbst) and a smaller one delivering 300 kgp (660 lbst). This made it possible to perform a take-off and climb at maximum thrust with both chambers running, then shut down the bigger chamber and use only the smaller one in level flight when detecting a target and attacking it. This resulted in a considerably lower fuel consumption and greater endurance. This solution was to a certain extent the right one, since other ways of throttling down a liquid-fuel rocket motor at high altitudes, where maximum thrust was not required, were highly problematic. Initially it was envisaged that this motor would be installed in the ***Malyutka*** rocket-propelled interceptor, development of which was entrusted to Nikolay N. Polikarpov in 1944; the untimely death of the designer led to the project being shelved. Later it was suggested that this engine be installed in new rocket-propelled interceptors, then under development in Artyom I. Mikoyan's OKB-155 and Semyon A. Lavochkin's OKB-301.

During the state acceptance trials of the RD-2M3V conducted in May 1945 the performance obtained included an aggregate take-off thrust of 1,500 kgp (3,310 lbst) with both chambers working, a nominal thrust of 1,250 kgp (2,760 lbst) and a minimum thrust of 500 kgp (1,100 lbst). With only the smaller chamber ignited the maximum thrust was 300 kgp and the minimum thrust 100 kgp (220 lbst). The specific thrust per 1 kg (2.205 lb) of fuel with both chambers running or only the smaller chamber working in maximum thrust mode was 200 kgp (440 lbst). The weight of the fully dressed engine was a mere 224 kg (493 lb). Plans called for the manufacture of 30 shipsets of the engine intended for the interceptors developed by OKB-155 and OKB-301, as well as for experimental aircraft developed at NII-1. Plant No.165 was tasked with manufacturing the engines, their assembly and check-up tests being entrusted to NII-1.

However, the problem posed by the engine development was not the only one that the designers of high-speed interceptors were confronted with. One of the peculiarities of such an aircraft lay in the fact that the limited fuel supply allowed it to perform virtually only one brief attack right away, and this posed serious limitations on the armament to be used. A fighter having a high weight of fire and a small ammunition load had appreciably better chances of destroying the target than a fighter with a greater ordnance load but with a low weight of fire (there was simply not enough time to expend the ammunition supply). For this reason the traditional cannon armament had to be replaced by rocket armament.

In 1943 the KB-2, a design bureau led by Chief Designer Artem'yev and subordinated nominally to the People's Commissariat of Agricultural Machinery, was approaching the completion of its development work on the 82-mm (3.14-in) TRS-82 unguided rockets designed by Pobedonostsev. The TRS stood for ***toor**boreak**tiv**nyy sna**ryad*** – literally 'turbo-jet projectile' (not to be confused with turbo-jet engines). As distinct from the well-known RS-82 projectiles which were widely used by Soviet attack aircraft and fighters during the war, they lacked stabilising fins and were spin-stabilised in flight, their rotation around the longitudinal axis being imparted by the efflux of blast gases through six slightly canted nozzles. This helped reduce projectile scatter, and it was considered that a salvo of six or ten such projectiles against a target offered better chances of a 'kill' than a prolonged firing of cannons. The engineers of KB-1 headed by Chief Designer I. P. Shebanov – the design bureau of plant No.81 subordinated to NKAP – developed special single-round launch tubes for the TRS-82 projectiles. Designated ORO-82 (*odi**noch**noye reak**tiv**noye o**roo**diye* – lit. 'single rocket gun'), they were smooth-bore tubes with an orifice at the aft end for the efflux of the blast gases. Apart from conventional underwing installation, these devices could be buried in the fuselage, thereby substantially reducing the aircraft's drag.



An artist's impression of the projected La-5VI high-altitude fighter (*vysotnyy istrebitel'*) – Sergey P. Korolyov's derivative of the Lavochkin La-5 fitted with three liquid-fuel rocket boosters under the wings and in the tail.

Aleksey Mikhaïlovich Isayev (1908-1971). Widely known for his work on the development of liquid-fuel rocket motors intended for aircraft, submarines and space vehicles. Since 1942 he was engaged in the design of rocket motors, from 1944 onward he headed a design bureau in the capacity of Chief Designer. In 1948 the design team headed by A. M. Isayev was transferred from the Moscow/Khimki-based branch of NII-1 (Plant No.293) to NII-88; in 1956 his team became an independent institution as the Design Bureau of Chemical Machine-building.

However, the availability of a suitable engine and suitable armament was not enough to guarantee the destruction of a high-speed aerial target. It was necessary not only to detect an enemy aircraft, but also to keep it within the crosshairs of the gunsight. As is well known, during the Second World War the USA, Great Britain and Germany produced in quantity interceptors fitted with aerial intercept (AI) radars. Their use in combat yielded certain positive results. Similar work was conducted in the USSR during the war. The engineers of the NII-20 research institute pertaining to the People's Commissariat of Electrical Engineering (NKEP – *Na**rod**nyy komissari**aht** elek**tri**cheskoy pro**mysh**lennosti*) developed metric-waveband AI radars. Two such radars, designated Gneis-2 and Gneis-5 (developed in 1942 and 1944 respectively), were adopted for operational service. However, the large dimensions of these devices, their high power consumption, the special requirements applied to the aerials' location and the need for a radar operator precluded the installation of these radars on single-engined fighters. In 1943 attempts were made to convert Douglas A-20B and A-20G Boston twin-engined bombers obtained under the Lend-Lease agreement into night fighters, but the Boston's speed and altitude performance was clearly inadequate for performing intercept missions. Moreover, the radars had many drawbacks (insufficient detection range, low precision, the presence of a 'blind spot') which did not permit a full-fledged attack – during the final stage of closing in on the target the pilot had to resort to the Mk 1 eyeball before firing. The effectiveness of such interceptors was fairly low. More advanced AI radars were needed to solve the tasks of interception. In late 1944 the development of such radars was entrusted to NII-17 – a research institute set up specially for that purpose within the framework of NKAP; engineers who had worked on the development of the Gneis radars were transferred to the new institute.

It should be mentioned that after the war the designers engaged in developing the Soviet rocket-propelled interceptors had an opportunity to get acquainted with German hardware captured by Soviet troops; this included the production Messerschmitt Me 163 Komet rocket-propelled interceptor. Several machines of this type were delivered to the USSR for thorough examination and testing. True, flight testing was limited to the glider mode, the Me 163 being towed by a Tupolev Tu-2 bomber (this was due to the unavailability of the proper *C-Stoff* and *T-Stoff* fuel components for the captured liquid-fuel rocket motors). However, the design features of the Me 163 were subjected to very careful study.

In addition to questions related to the powerplant of the rocket-propelled interceptor, its armament and equipment, it was necessary to find the answers to questions pertaining to high-speed flight aerodynamics. Research of that kind was conducted in the Central Aero- & Hydrodynamics Institute named after Nikolay Ye. Zhukovskiy (TsAGI – *Tsen**trahl'**nyy **a**ero- i **ghid**rodina**mich**eskiy insti**toot***). Albeit this institute had at its disposal the captured research materials on the layouts of German high-speed aircraft (with sweptback and forward-swept wings), it was necessary to conduct a vast programme of the institute's own research before it could submit its recommendations to the Soviet design bureaux. Unfortunately, TsAGI had only one high-speed wind tunnel, the T-106, with a working zone measuring 2.6 m (8 ft 6 in) in diameter and the airflow speed reaching 900-950 km/h (559-590 mph); yet, even this wind tunnel stood idle most of the time due to frequent power failures. As for the construction of new wind tunnels, there were no such plans right after the war.

Leonid Stepanovich Dooshkin (1910-1990). From the late 1930s he headed a liquid-fuel rocket motor design group at NII-3 (in January 1938 all sections of NII-3 were renamed groups). NII-3 was formed in 1933 on the basis of the GDL and the Moscow Group for the Study of Rocket Propulsion (MosGIRD – *Moskovskaya grooppa izucheniya reaktivnovo dvizheniya*). It was the first research institution in the USSR to deal with rocket propulsion issues; accordingly, it was then named RNII (Rocket Propulsion Research Institute). In early 1937 it was renamed NII-3 and transferred into the system of People's Commissariat of Defence Industry. From 1942 it bore the name of Jet Aviation Research Institute (or NII-1) and was transferred to the NKAP system.

Still, the NKAP top brass (above all, People's Commissar Aleksey I. Shakhoorin and his deputy Aleksandr S. Yakovlev) displayed reserve in making a serious stake on rocket-propelled aircraft, mindful of the preceding unsuccessful attempts to build the first Soviet interceptors powered by liquid-fuel rocket motors. The aircraft in question were the BI (developed in Viktor F. Bolkhovitinov's OKB and the '302' aircraft developed at the State Institute for Rocket Technology (GIRT – *Gosoo**dar**stvennyy insti**toot** po ra**ket**noy* ***tekh**nike*) under the Soviet Council of People's Commissars, headed by A. G. Kostikov. For this reason the issue of copying the Me 163 was not raised (unlike the idea of copying the twin-turbojet Me 262 Schwalbe fighter). Yet, the plan for prototype construction for 1946 endorsed by a Council of People's Commissars directive included two almost identical tasks for the development of rocket-propelled interceptors. These assignments were given to OKB-155 led by Artyom I. Mikoyan and OKB-301 led by Semyon A. Lavochkin; in the latter case, the fighter was to be fitted both with rocket projectiles and a *radar sight* (AI radar).

These and preceding projects are dealt with in detail in the subsequent chapters of the book.

Chapter 1

The Pioneering BI

Maj. Gen. Viktor F. Bolkhovitinov, Chief Designer of OKB-293 and Director of plant No.293.

BI Short-Range Interceptor

In the early spring of 1941 the engineers Aleksandr Yakovlevich Bereznyak and Aleksey Mikhaïlovich Isayev started work on the advanced development project (ADP) of a new type of interceptor. The two men were employees of the design bureau of plant No.293; this plant, which was managed by Chief Designer Viktor Fyodorovich Bolkhovitinov, had briefly become the experimental production facility of RNII. The latter institute was renamed NII-3 shortly after the outbreak of the war and transferred from the NKAP framework to the People's Commissariat of Ordnance (NKB – *Na**rod**nyy komissari**aht** boyepri**pah**sov*).

The designers opted to equip the projected fighter with a liquid-fuel rocket motor which, according to calculations, would give the machine a top speed of 800 km/h (496 mph) or even more. The project was as daring as it was simple – and, for the first time in world aircraft design practice, the rocket-propelled aircraft was designed from the outset as a combat aircraft, not a proof-of-concept vehicle. The interceptor's design concept followed almost exactly the idea of creating a rocket-propelled interceptor which, with remarkable foresight, Sergey P. Korolyov had voiced as early as 1938.

Many years later Aleksey M. Isayev recalled how the project was born.

'One fine day Bereznyak suggested, out of the blue: "Aleksey, let's develop a fighter powered by a liquid-fuel rocket motor."

"A liquid-fuel rocket motor? What on earth is that?" – I queried.

Aleksandr gave me a detailed description of Sergey Korolyov's RP-318 rocket-propelled powered glider which had been powered by a jet engine (sic) designed by L. S. Dooshkin. The idea appealed to me, and we started working. For more than a month we spent our spare time in the evenings choosing the optimum layout and finding the correct CG position. We got so carried away that our main job was sort of neglected. Eventually our 'odd job' activities were reported to the chief (that is, Chief Designer Bolkhovitinov – *Auth.*). *Viktor Fyodorovich studied our project materials carefully, smiled and said: "Well, this may work out right. Go ahead!"*

Bolkhovitinov fully realised that the future of aviation lay with jet aircraft, and he gave us full support. Almost every evening he would pay a visit to have a look at our drawings and calculations…'

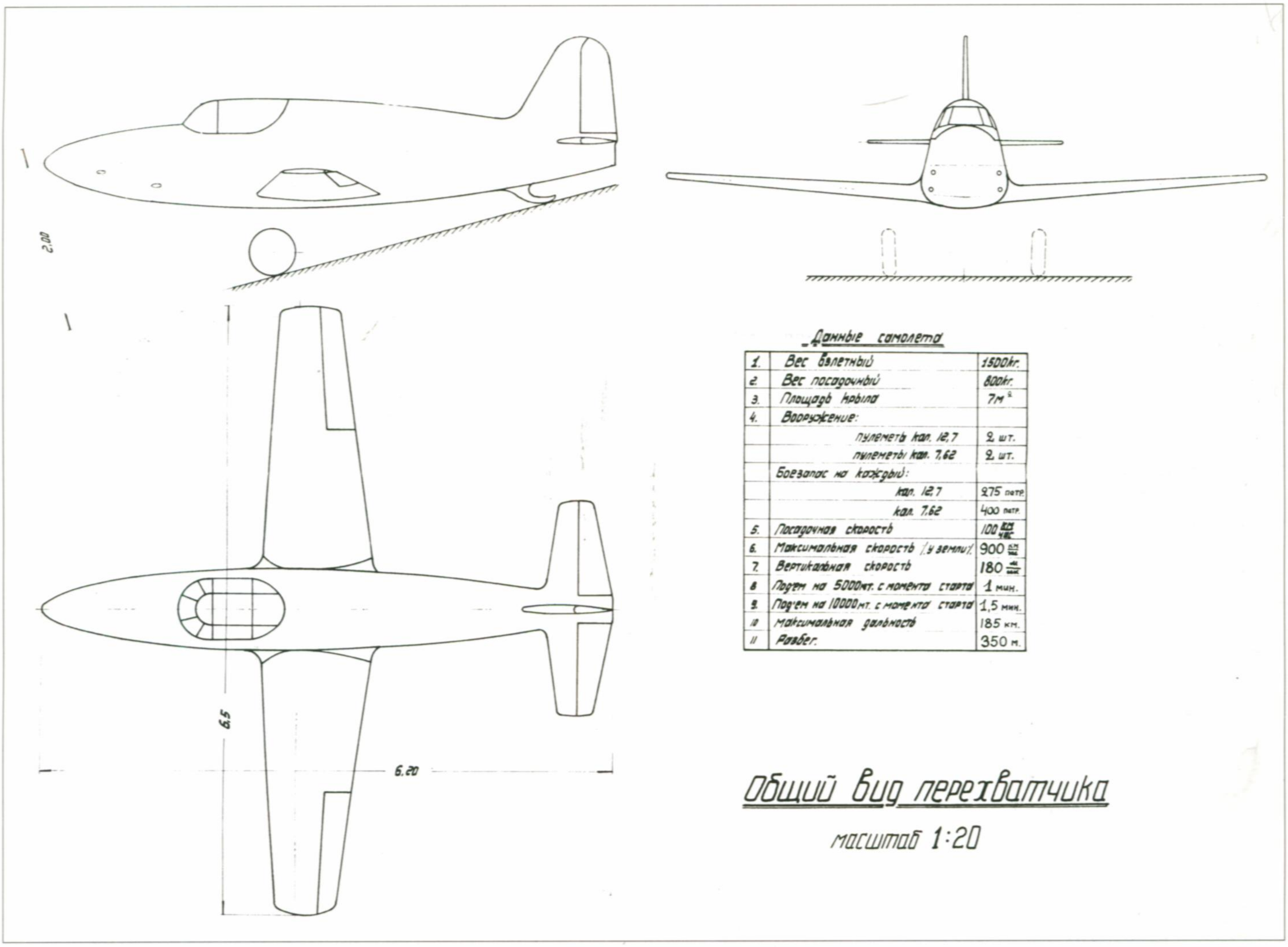
In 1940 Aleksandr Ya. Bereznyak and Aleksey M. Isayev had paid a visit to RNII and made the acquaintance of engine designer Leonid Stepanovich Dooshkin, who was supervising the development of a liquid-fuel rocket motor which was to be used as a take-off booster on the '302' interceptor then under development at RNII (see Chapter 2). Viktor F. Bolkhovitinov remarked that *'…Dooshkin's motors had very appealing thrust performance but were extremely "nasty" as regards fuel consumption. It appeared that the aircraft's endurance might be around 1 to 4 minutes, depending on the flight speed and altitude, because of the high fuel consumption.'* On the other hand, it transpired that an aircraft with such a powerplant boasted extraordinarily high speed and, importantly, an exceptional rate of climb as compared to any other aircraft.

This calls for some explaining. In the early 1930s the Soviet intelligence service had succeeded in obtaining materials on rocket motors (which, confusingly, were then referred to as 'jet engines'). The following conclusion made by Soviet specialists bears testimony to how valuable this intelligence was:

Aleksandr Ya. Bereznyak, the project chief of the interceptor eventually known as the BI.

'The said jet engine is the invention that scientists around the world have toiled over for many years. The introduction of this invention on a state-of-the-art basis will bring about an unfathomable revolution in aviation, especially in military technology. The materials obtained make it possible to start manufacturing [such] an engine in the Soviet Union.'

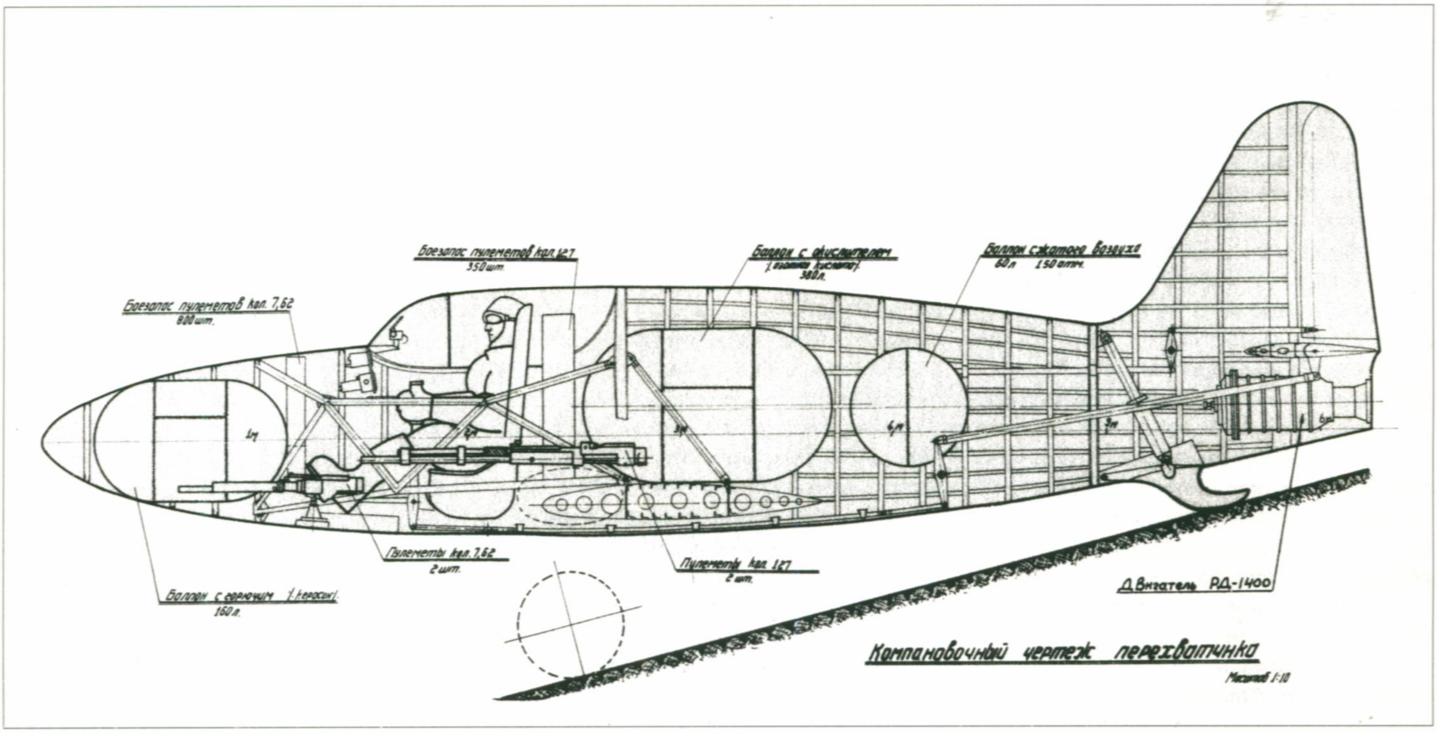
Efforts to adapt rocket motors to aircraft began almost simultaneously in Italy, Great Britain and Germany, the United States following suit shortly afterwards. The German scientists and engineers achieved the greatest success in this area. A certain German secret service (Gestapo) employee named Lehmann, who had been recruited by the Soviet intelligence service, kept the Soviet authorities well informed on the progress of this work in Germany. In particular, in late 1935 he had the chance to attend the tests held by the well-known – or should we say notorious? – Wernher von Braun, the man behind the V-2 ballistic missile which was used by the Germans against targets in southern England. 'In the forest, in a remote corner of the target range, stands for testing liquid-propellant rockets have been set up', the Soviet intelligence officer Zaroobin reported to Moscow after receiving the information from Lehmann. The Soviet intelli-



Данные самолета

1.	Вес взлетный	1500 кг.
2.	Вес посадочный	800 кг.
3.	Площадь крыла	7м²
4.	Вооружение:	
	пулеметы кал. 12,7	2 шт.
	пулеметы кал. 7,62	2 шт.
	Боезапас на каждый:	
	кал. 12,7	275 патр.
	кал. 7,62	400 патр.
5.	Посадочная скорость	100 км/час
6.	Максимальная скорость (у земли)	900 км/час
7.	Вертикальная скорость	180 м/сек
8	Подъем на 5000 мт. с момента старта	1 мин.
9.	Подъем на 10000 мт. с момента старта	1,5 мин.
10	Максимальная дальность	185 км.
11	Разбег.	350 м.

Above: A provisional three-view drawing of the still-nameless rocket-powered interceptor designed by Bereznyak and Isayev as it looked at the ADP stage. Note the tailskid located well forward, the position of the horizontal tail and the lack of stabiliser endplates.



A cutaway drawing from the ADP documents, showing (left to right) the 160-litre fuel tank, the 7.62-mm machine-guns, the 12.7-mm machine-guns (with dorsal ammunition boxes for 800 and 350 rounds respectively), the 380-litre oxidiser tank, the 60-litre air bottle charged to 150 kg/cm² and the RD-1400 rocket motor.

gence service submitted a detailed written report on these tests to the Soviet leader Iosif V. Stalin, Marshal Kliment Ye. Voroshilov (the then People's Commissar of Defence) and Marshal Tukhachevskiy. After that, the Soviet secret agents in Germany received a list of questions on military matters which they were to investigate, and Lehmann supplied the answers to many of the questions.

Coming back to the rocket-powered fighter under development at OKB-293, as early as the ADP stage the designers succeeded in tackling a number of major technical puzzles. The aircraft under development by Bereznyak and Isayev was originally intended to take a rocket motor delivering a thrust of 1,400 kgp (3,090 lbst) and featuring a turbine pump feeding the fuel to the combustion chamber. However, in order to speed up the work the complex turbine pump system, which required lengthy debugging, was discarded in favour of a simple and reliable system in which the fuel was displaced by compressed air from bottles charged to 145-148 kg/cm^2 (2,071-2,114 psi); the total capacity of the bottles was 115 litres (25.3 Imp gal). This allowed the airframe to be made smaller, with an attendant improvement in the aircraft's acceleration characteristics. This version powered by the Dooshkin D-1A rocket motor became the principal project version.

The originally nameless aircraft was eventually designated BI, and this designation warrants special attention. The authors of many published works on this aircraft claim that BI stood for Bereznyak and Isayev. True enough, after the breakout of the Great patriotic War on 22nd June 1941 the old Soviet aircraft designation system based on the aircraft's role (I for *istre**bit**el'* – fighter, TB for *tya**zhol**yy bombardi**rov**shchik* – heavy bomber, PS for *passa**zheer**skiy samo**lyot*** – airliner and so on) gave place to a new system using the first letters of the Chief Designer's (or designers') last name – 'Yak' for Yakovlev, 'La' for Lavochkin, 'Tu' for Tupolev and so on, and some existing aircraft were redesignated accordingly. However, in the advanced development project of 1941 the rocket-propelled interceptor bore no designation at all – it was some time before the BI designation appeared. Now neither Bereznyak nor Isayev were famous designers at the time, so there was no real reason why the aircraft should be named after them; they worked as chiefs of the mechanism design team and the engine design team respectively, reporting to Chief Designer Viktor F. Bolkhovitinov. The latter, conversely, was already a well-known figure in the Soviet aircraft industry, so theoretically the fighter should have been named after him.

In actual fact the designers of the aircraft 'killed all birds with one stone' by consciously sticking to the old system – a solution which suited both them and the authorities. The truth is that 'BI' officially stood for ***blizh**niy istre**bit**el'* – short-range fighter, which is exactly what it was. However, 'BI' could also be deciphered at will as Bereznyak/Isayev, or as *Bolkhovi**tin**ova istre**bit**el'* – Bolkhovitinov's fighter (which, according to the memoirs of some people involved, was how the Chief Designer had planned it). The leaders of NKAP had not attached much importance to this ambiguity. In fact, several documents contain the following phrase: 'BI aircraft designed by Major-General of Aircraft Engineering Comrade Bolkhovitinov V. F.'.

However, we have to return to the ADP of 1941 once again. The following extracts from it may be of interest to the reader:

NKAP plant No.293 – NII-3 of NKB
ADVANCED DEVELOPMENT PROJECT OF AN INTERCEPTOR
1941

After four months' work we have succeeded in developing a new type of interceptor aircraft. Its specifications are as follows:

	Interceptor		***Fighter****
Take-off run, sec	*9*	*versus*	*11-17*
Acceleration to, sec†	*20*	*versus*	*90-120*
Climb time to 5,000 m [16,400 ft], sec	*30*	*versus*	*270-350*
Time/distance to catch up with a bomber flying at 400 km/h [248 mph], sec	*10 km in 70-80 sec*	*versus*	*10 km in 200-400 sec*
Top speed, km/h [mph]	*850-900 [528-559]*	*versus*	*550-650 [341-403]*
Endurance, min	*5*	*versus*	*45-60*
Range, km [miles]	*100-200 [62-124]*	*versus*	*700-1,000 [434-621]*

[* that is, a typical contemporary fighter. † *sic*; probably 'acceleration to maximum speed' – *Auth.*]

It is armed with two 12.7-mm [.50 calibre] machine-guns with an ammunition supply of 275 rounds per gun and two 7.62-mm [.30 calibre] machine-guns with an ammunition supply of 400 rounds per gun.
The engine is a jet engine – an RD1400 developed by NII-3 of NKB; it weighs 45 kg [99 lb] and, when installed on the interceptor, delivers up to 4,500 hp (sic) while having a length of 800 mm [2 ft 7½ in]and a diameter of 320 mm [1 ft $0\frac{19}{32}$ in].
The fuel supply for the flight is 135 kg [297 lb] of tractor-grade kerosene and 570 kg [1,256 lb] of nitric acid.
The interceptor's dimensions and weight are 50% smaller than a fighter's.

	Weight	***Wing area***	***Wing span***
Conventional fighter	*3,000 kg [6,610 lb]*	*14-20 m^2 [150.5-215.0 sq ft]*	*12-14 m [39 ft $4\frac{7}{16}$ in to 45 ft $11\frac{3}{16}$ in]*
Interceptor	*1,500 kg [3,305 lb]*	*7 m^2 [75.26 sq ft]*	*6.5 m [21 ft $3\frac{29}{32}$ in]*

What can this interceptor do that [conventional] fighters cannot?
1. Sitting on the ground on ready alert, on sighting an enemy aircraft flying at any altitude up to 10,000 m [32,810 ft], in any [horizontal] visibility conditions ranging from 10 to 1 km [from 6.2 to 0.6 miles] it can catch up with the enemy aircraft and engage it:

- *in 30 seconds if the visibility and the [target's] altitude are 1,000 m [3,280 ft];*
- *in 60 seconds if the visibility and the altitude are 5,000 m [16,400 ft];*
- *in 90 seconds if the visibility and the altitude are 10,000 m [32,810 ft].*

A very important fact is that about 25 seconds of this time are spent near the ground for taking off and accelerating to 900 km/h [559 mph], which leaves the adversary between 5 and 60 seconds for detecting the attacker and preparing for defence. The interceptor has more than twice the speed of bombers and 50% higher speed than fighters, while the advantage in rate of climb is sevenfold.

2. It can catch up with the bomber and attack it at night, since the period when the bomber is caught in the air defence's searchlights is ample for closing in. The interceptor's landing speed is just 100 km/h [62 mph].

3. It can attack the target from any angle, even from underneath, commencing and breaking off the engagement at will thanks to the superior speed, rate of climb and acceleration as compared to enemy fighters.

4. It does not waste fuel on loitering in patrol mode.

5. If armed with eight RS-82 rocket projectiles or a cable which is let down before attacking the enemy (in the manner of barrage balloons – Auth.), *it can engage close formations of enemy aircraft before they have a chance to scatter.*

What is it this interceptor cannot do that fighters can?

1. Stay aloft for an extended time, – but then, it does not need that, since its performance enables it to fulfil the mission right after taking off.

2. Cover long distances – its range is 100-200 km [62-124 miles]. However, this applies to the first examples of the aircraft; the range can be extended later on.

The interceptor is easy to operate and reliable in operation. It requires a minimum of maintenance; once the machine has been refuelled, it is ready for action – in any season and at any ambient temperature. It contains no media that can freeze – neither oil nor water (engine oil and coolant – Auth.). *There is no need to test or prepare anything before the flight. For maintenance it requires 1.5 to two times less ground personnel than a conventional fighter.*

It is very easy to manufacture, since:

1. the engine that has made possible the creation of such an interceptor (it has been developed, built and tested both on a ground rig and in flight on a powered glider by Research Institute No.3 of NKB) is a simple turned 'pot' made of Cromansil steel; thus

a) it can be manufactured by any mechanical workshop;

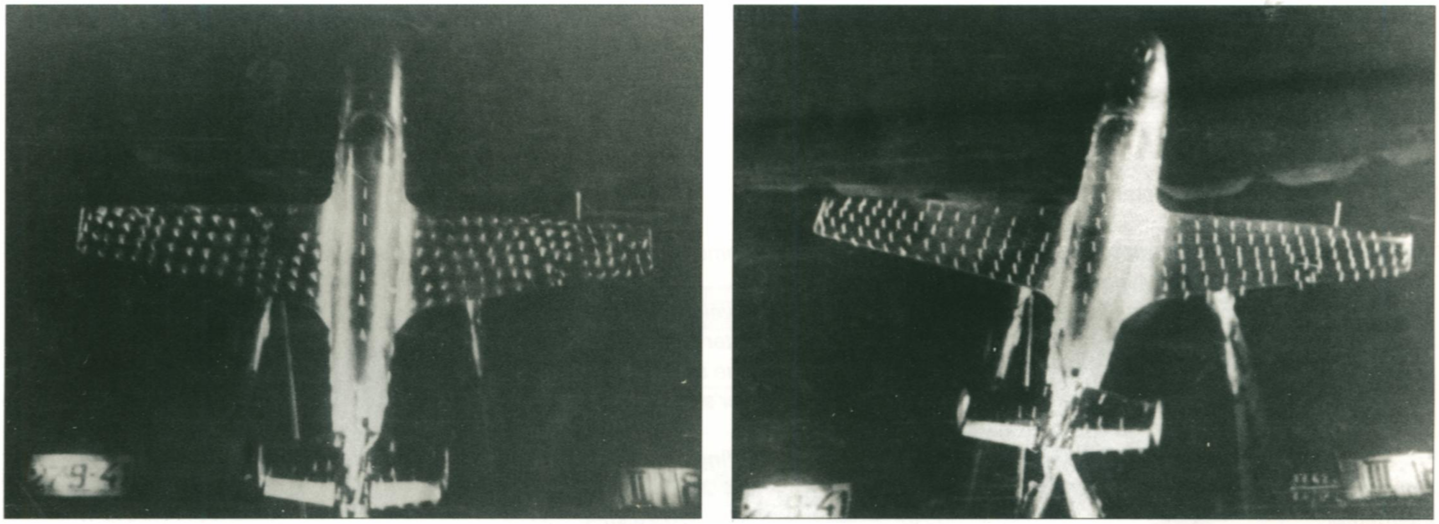
b) it comprises 50-100 parts versus 3,000 for a conventional aero engine;

c) it does not require any accessories, namely airscrews, governors, filters, magnetos, self-starters, pumps, radiators, superchargers etc. etc.

2. The aircraft is small, measuring 6 x 6 m [19 ft $8\frac{7}{32}$ in x 19 ft $8\frac{7}{32}$ in], and may be manufactured from any materials (not necessarily top-quality ones) at any furniture factory, not a specialised aircraft factory; it has just nine flight instruments versus 16 on a conventional fighter, and its manufacturing labour intensity is two to three times lower.

Therefore, we (NII-3 and plant No.293) are in a position to design and build the engine and the aircraft within three months at the cost of 6 million roubles.

(signed)
Director of NII-3 Monakov
Director of plant No.293 Bolkhovitinov
Chief Engineer of NII-3 Kostikov
Chief Engineer of plant No.293 Volkov
Designer of the engine Dooshkin
Designers of the aircraft Bereznyak, Isayev



Left and right: A full-size airframe of the BI undergoing tests in TsAGI's T-101 wind tunnel. Note the wool tufts on the wings and tail; note also the endplate fins.

Thus, the designers placed their bets on a steep (almost vertical) climb towards the target and on the interceptor's high rate of climb. The idea was that when the enemy bomber would be within one or two minutes' flight time from the base, the interceptor would scramble and attack instantly, making use of its nearly two times higher speed. However, the fuel supply allowed for only one attack – there would be no second chance. If the bomber was doing up to 600 km/h (372 mph) at 5,000 m (16,400 ft), the interceptor could attack it within a minute after take-off – providing the pilot did not lose the target in so doing.

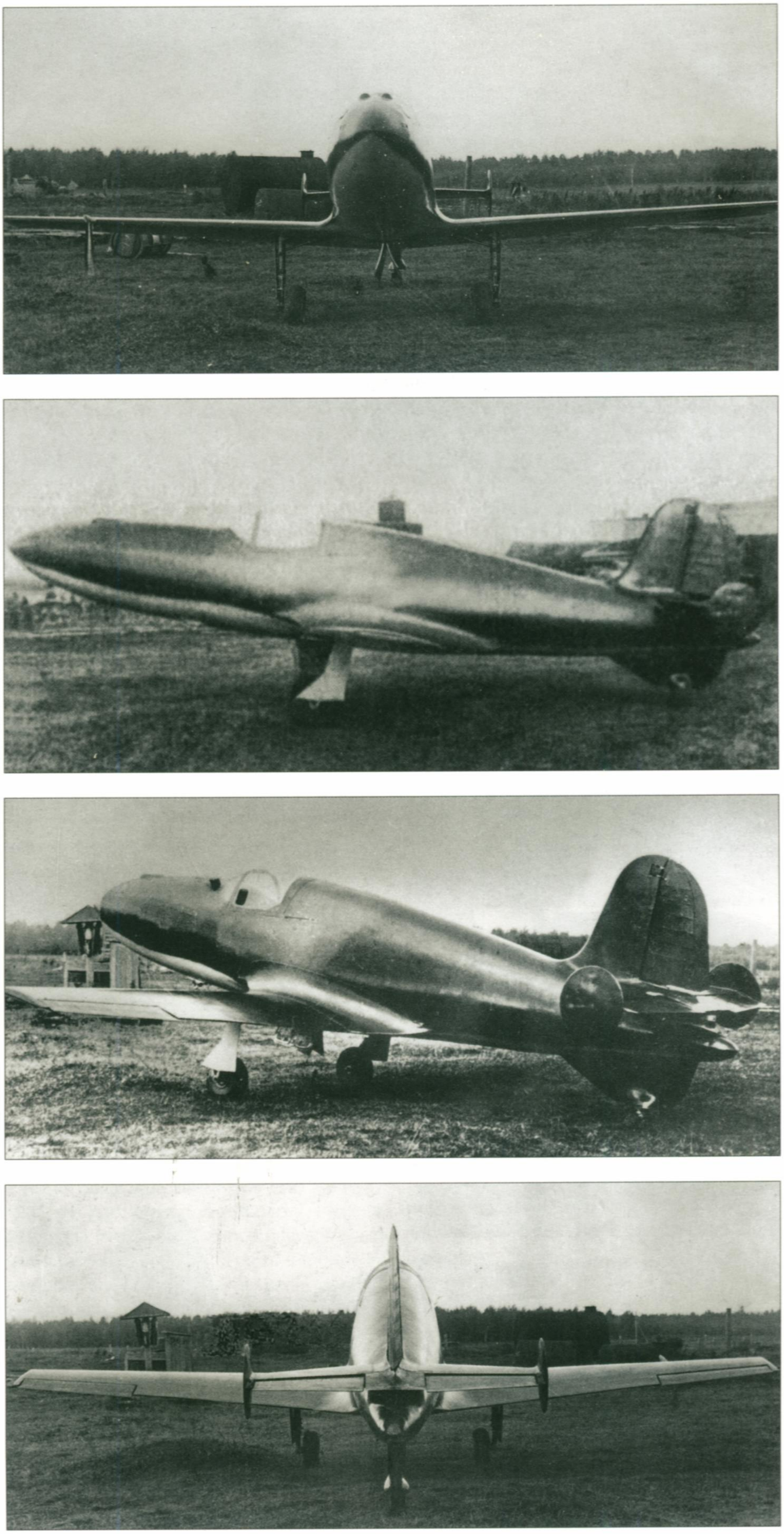
The aircraft was a single-seater with cantilever low-set wings and the airframe was of largely wooden construction, the liquid-fuel rocket motor being housed in the rear fuselage. The relatively simple design made it possible to launch mass production of the interceptor, using non-strategic structural materials and any available manufacturing facilities, which made the jet interceptor an especially valuable asset in times of war.

The ADP stage was completed in just 12 days. According to the project the aircraft had a wing span of just 6.5 m (21 ft $3\frac{29}{32}$ in) and was 6.4 m (21 ft 0 in) long; the fully retractable landing gear was pneumatically actuated. The take-off weight was 1,650 kg (3,640 lb), the kerosene fuel and the nitric acid oxidiser accounting for 710 kg (1,565 lb).

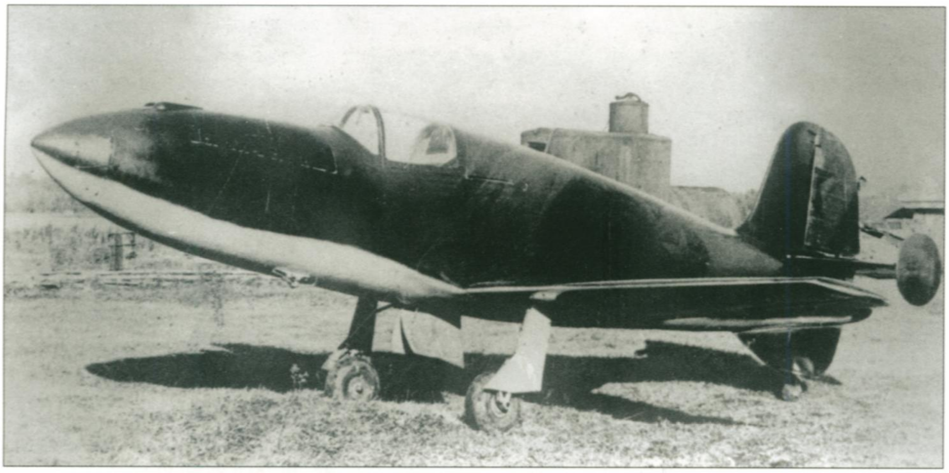
When the war broke out, the designers suggested that the head of OKB-293 Viktor F. Bolkhovitinov should submit a draft of a government directive officially ordering the aircraft's development. An official letter was drawn up by RNII and plant No.293, initialled by the seven persons who were the motive power of the project, including the aircraft's designers A. Ya. Bereznyak and A. M. Isayev, the engine's designer L. S. Dooshkin, the plant's director V. F. Bolkhovitinov and its chief engineer Andrey G. Kostikov. The letter was sent on 9th July 1941, with the result that all seven signatories were summoned to the Kremlin shortly afterwards.

People's Commissar of Aircraft Industry Aleksey I. Shakhoorin and his deputy Aleksandr S. Yakovlev approved the team's proposal and drafted a Council of People's Commissars directive which was duly endorsed a few days later in August 1941. A State Defence Committee (GKO) directive signed by Iosif V. Stalin tasked the Bolkhovitinov OKB with creating an interceptor powered by a liquid-fuel rocket motor within extremely tough time limits – just 35 days instead of the three months Bereznyak and Isayev had requested. The same document ordered NII-3 (the former RNII) headed by A. G. Kostikov to develop the RDA-1-1100 liquid-fuel rocket motor (later it was referred to in many documents as the RD-1-A-1100). The GKO directive was backed up by a revised NKAP order to the same effect.

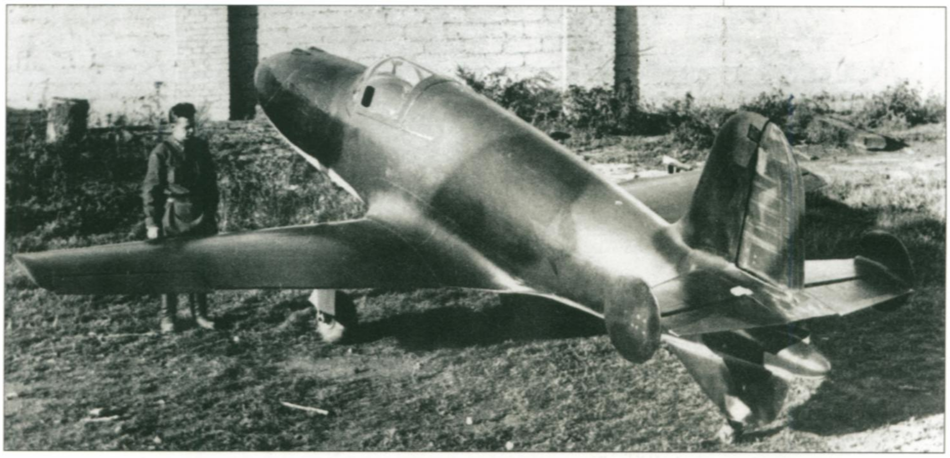
Bolkhovitinov's OKB was tasked with the development of fuel tanks and the system of fuel feed to the rocket motor incorporating the basic hydraulic layout evolved by NII-3, while Dooshkin's OKB forming part of NII-3 was tasked with ensuring the functioning of the rocket motor in a variable mode, with thrust settings from 400 to 1,100 kgp (882-2,425 lbst) and with a possibility of repeatedly restarting the motor. The engine which was under development at NII-3 under the direction of L. S. Dooshkin and V. A. Shtokolov delivered at that time a thrust of not more than 600 kgp (1,320 lbst) instead of the required 1,100 kgp (2,425 lbst). The chief designer of the rocket motor wrote:

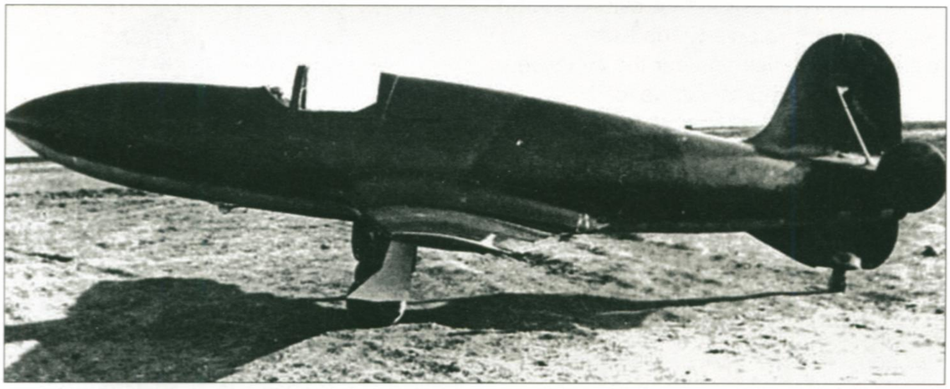


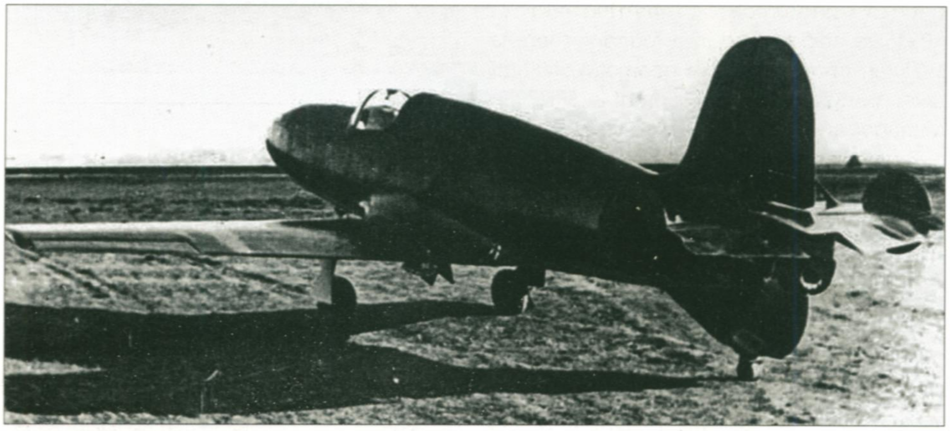
Four aspects of the engineless first prototype BI used for initial gliding tests. The real aircraft was rather rather different from the ADP drawings. Note the faired-over rocket motor nozzle and the lack of insignia.



Above and below: Two more views of the first prototype (BI No.1), still engineless but with red star insignia applied. Note the cannon access panel on top of the nose and the direct vision window in the canopy.







Centre and above: The same aircraft following the installation of the D-1A-1100 rocket motor and the addition of bracing struts between the fin and stabilisers. No armament is fitted.

'In its final configuration the motor was to deliver controllable thrust within the range of 350 to 1,110 kg [770-2,450 lbst]; it was to have a specific thrust of no less than 200 sec and an engine life of no less than 20 minutes or a continuous operation time of no less than 3 minutes.

*Such a motor was being developed on the basis of the RDA-1-150 design and was designated D-1-A-1100 (D-1 stood for "***dvig***atel'* ***per****vyy" – motor No.1, the A stood for "a***zot***naya kislo***ta***" – nitric acid, and 1100 denoted the nominal thrust of 1,100 kg).'*

Following the issuance of the GKO directive and the NKAP order, the Bolkhovitinov OKB introduced military-style work regulations; its personnel worked for exactly a month and ten days without leaving the factory. Designers of the aircraft undertook an attempt to order in the NKEP (People's Commissariat of Electric Engineering) the so-called 'radio device for detecting aircraft' (***rah****dio'is***kah***tel samo***lyo***tov*, or RIS – a term presumably referring to what later became known as radar) to be installed on their interceptor, but their initiative met with no support.

The fighter was manufactured almost without detail drawings; its parts were drawn in full size on a sheet of plywood, using mould lofts. The small dimensions of the aircraft made this task easier. No particular difficulties were foreseen as regards the manufacture of wooden parts of the structure, while the undercarriage – the only complicated piece of engineering on the aircraft – was subcontracted to another enterprise. By 1st September the first flying example of the BI aircraft (BI No.1 or BI-1) was sent for testing to NKAP's Flight Research Institute (LII NKAP – ***Lyot****no-is***sled***ovatel'skiy insti***toot*** *Na***rod***novo komissari***ah***ta aviatsi***on***noy pro***mysh***lennosti*).

Initially the aircraft performed high-speed taxi runs and hops on tow, while the development work on the engine was not yet started. The fighter's design incorporated many novel elements; the work with nitric acid, which corroded the tanks and piping, was particularly difficult. A whole set of measures intended to ensure safety was required, since even the fumes of nitric acid harmed the human system; on some occasions the personnel sustained chemical burns. Eventually it proved possible to cope with this problem somehow.

Being utterly pressed for time, the designers had to start the development work on the rocket motor right away as a part of the aircraft's development, using the test bench in Bolkhovitinov's OKB; the autonomous trials stage had to be skipped. The tests began as early as September 1941. The development work was primarily aimed at ensuring the reliable functioning of the motor starting system.

In response to a stipulation issued by Aleksandr S. Yakovlev, deputy People's Com-

Above left: Capt. Grigoriy Ya. Bakhchivandzhi, the BI interceptor's second project test pilot – and the first to make a powered flight in the BI.
Above right: A drawing depicting the 'mighty foursome' – the people involved in the development and testing of the BI – in front of the aircraft. Left to right: airframe designer A. Ya. Bereznyak, propulsion system designer A. M. Isayev, test pilot G. Ya. Bakhchivandzhi and OKB-293 head V. F. Bolkhovitinov.
Below, centre and bottom: Bakhchivandzhi dons his flight helmet and climbs into the BI-1's cockpit before a test flight.

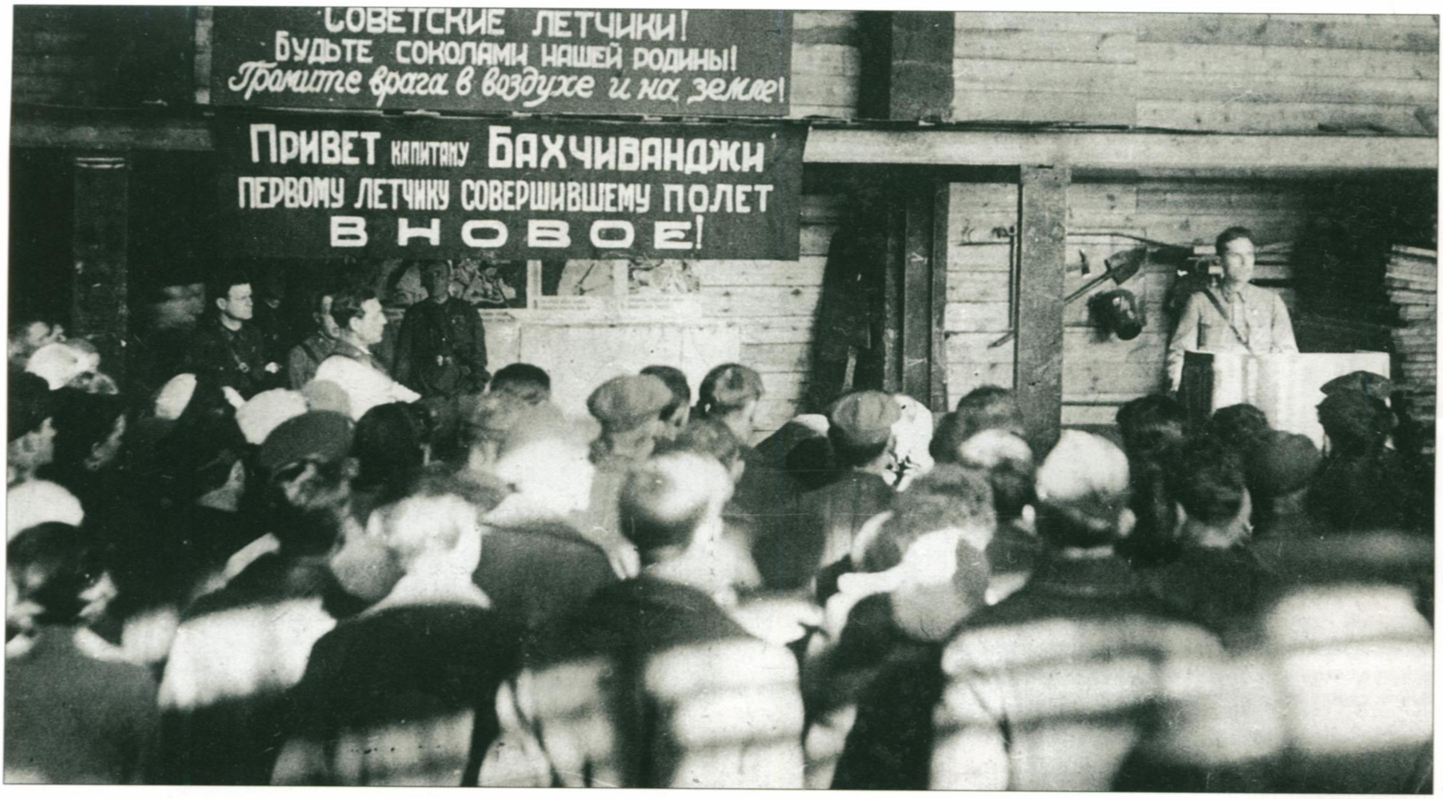
missar of Aircraft Industry responsible for prototype aircraft construction, the airframe of the BI aircraft was prepared for tests in the TsAGI wind tunnel permitting the testing of full-size aircraft. Wind tunnel tests with the BI were conducted under the direction of G. S. Büschgens and A. L. Reich. Immediately after the completion of the aerodynamic research the aircraft commenced flight testing in glider configuration, towed by a Pe-2 dive bomber; the rocket motor nozzle was closed by a fairing at this stage.

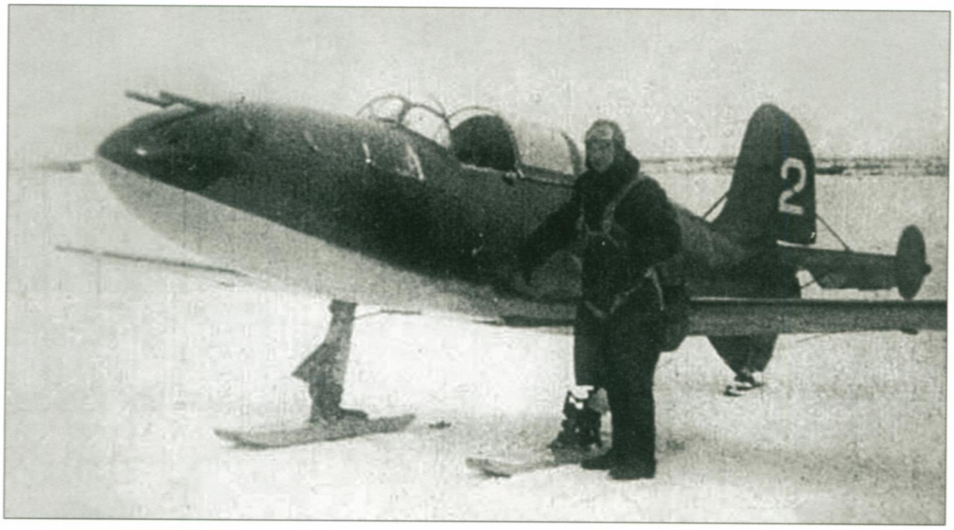
The BI was an extremely compact fighter – its length was 6.9 m (22 ft 7¾ in), the wing span being 6.6 m (21 ft 8 in). It was a single-seat low-wing monoplane of wooden construction with straight wings and a retractable undercarriage. In 15 unpowered flights test pilot Boris N. Koodrin registered all the basic flying characteristics of the first BI prototype at low speeds. The tests corroborated that all the aerodynamic characteristics of the aircraft, its stability and controllability were in accordance with calculations. It was impossible to do more before the German advance forced an evacuation.

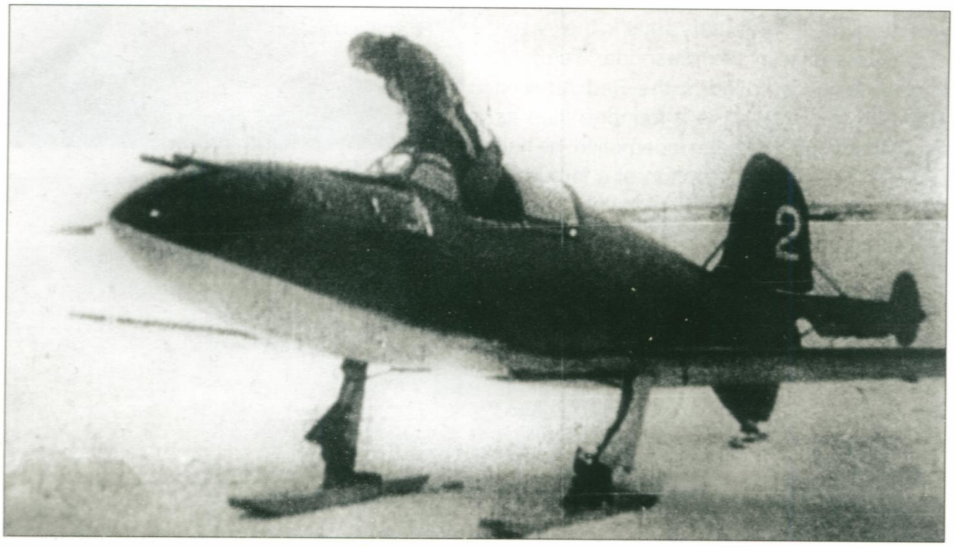
On 16th October a decision was taken to evacuate the OKB and plant No.293 to the Urals. On the following day the test bench was dismantled, all the hardware and documentation were sent to Sverdlovsk (now renamed back to Yekaterinburg). On the days following the 20th October NII-3 of NKB, together with L. S. Dooshkin's OKB, was evacuated to the same destination.

In December 1941, after the redeployment to the Urals, the work on the BI resumed in a small town of Bilimbai situated some 60 km (37 miles) from Sverdlovsk. The OKB and plant No.293 were accommodated on the territory of an abandoned foundry that had fallen into disrepair; within a short space of time restoration work was performed on the premises in extremely harsh conditions. To continue the development of the aircraft's powerplant, a small temporary hut made of plywood was erected on the bank of a reservoir adjoining the plant, on what had formerly been a dam; this structure provided accommodation for a cradle-shaped test rig. The tests were conducted under the direction of A. V. Pallo, a representative of NII-3, and Roslyakov, an employee of OKB-293. Test pilot Boris N. Koodrin, who had fallen ill, was replaced by Captain G. Ya. Bakhchivandzhi whom the Air Force Command entrusted with the task of conducting the flight testing of the BI aircraft.

A few words need to be said about this pilot. Grigoriy Yakovlevich Bakhchivandzhi was born on 20th February 1909 in the village of Brinkovskaya in the Krasnodar Territory. Prior to being enrolled in the Red Army in 1931, he had worked in a foundry, then as assistant driver of a steam locomotive; he had taken part in the construction of a factory in Mariupol’ and worked as a mechanic there. In 1934 he graduated from the Orenburg Military Flying School; as early as 1935 he became a test pilot at the Air Force Research Institute (NII VVS – *Na**ooch**no-is**sled**ovatel’skiy insti**toot** Vo**yen**no-voz**doosh**nykh seel*). At first Bakhchivandzhi flew reconnaissance aircraft, then fighters; some time later the flight testing of aircraft engines became his particular domain. In 1941 the war interrupted his work as test pilot; Bakhchivandzhi joined combat as a pilot of the 402nd special Fighter Regi-


СОВЕТСКИЕ ЛЕТЧИКИ!
БУДЬТЕ СОКОЛАМИ НАШЕЙ РОДИНЫ!
Громите врага в воздухе и на земле!
ПРИВЕТ капитану БАХЧИВАНДЖИ
ПЕРВОМУ ЛЕТЧИКУ СОВЕРШИВШЕМУ ПОЛЕТ
В НОВОЕ!





Above: A festive meeting of the staff of OKB-293 and the personnel of plant No.293 to celebrate the BI's first powered flight. The slogans read: 'Soviet pilots! Be the falcons of our Motherland! Give the enemy what-for in the air and on the ground!' and 'Hail Captain Bakhchivandzhi, the first pilot to make a flight into the New!'

Left: Grigoriy Bakhchivandzhi poses beside the ski-equipped second prototype (BI No.2), '2 White'.

Below left: Bakhchivandzhi climbs into the cockpit of the BI No.2. Note the protruding cannon barrels.

ment (IAP – *istre**bit**el'nyy **aviapolk***) into which the flight test detachment of NII VVS had been transformed. Between 1st July and 10th August Bakhchivandzi flew 72 combat sorties, shooting down six German aircraft in the skies of Moscow. In mid-August 1941 he, as a specialist in the testing of aero engines, was recalled from the front to continue his test work at NII VVS.

Aleksey M. Isayev, a direct participant of the development work and one of the designers of the BI aircraft, recalled the events of the late 1941 and early 1942 as follows:

'When we heard over the radio the news that war had broken out we were confused. What next? What should we do? What would happen with our aircraft to which Bolkhovitinov had already given the designation BI-1?

In response to a presentation made by our chief, the then People's Commissar of Aircraft Industry A. I. Shakhoorin approved our idea. A draft directive of the State Defence Committee was prepared, as well as a draft NKAP order to follow it up. We received just one month for the whole thing – not just for the preparation of the

Right: Chief Designer Maj. Gen. Viktor F. Bolkhovitinov (second from right) congratulates Bakhchivandzhi after a successful test flight in the BI No.2.

project or of the manufacturing drawings, but also for the construction of the real aircraft! We asked for at least three to four months. Shakhoorin listened to us and added five days to the abovementioned term.

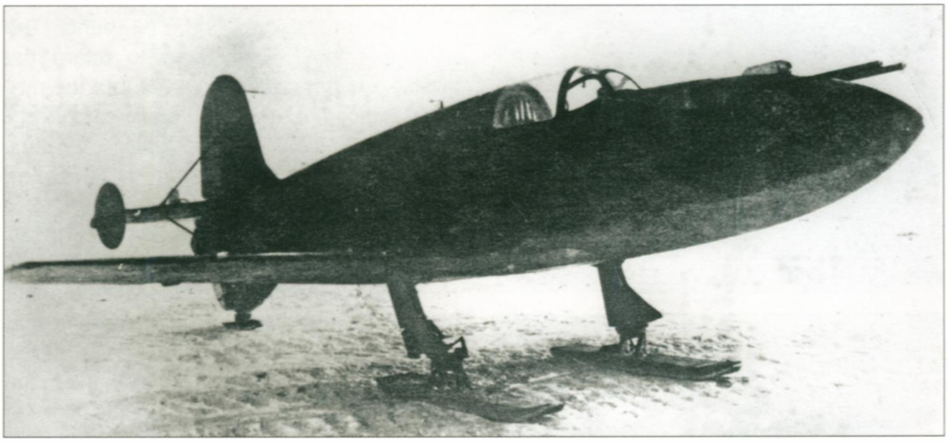
The war dictated the conditions of our work. Technical drawings made on heavy drawing paper were sent to the workshop right away. Workers took the measurements from them, manufactured dummies and half-finished articles. The lathes on which the parts of the rocket motor were turned were kept in operation round the clock. In retrospect, it is clear that many parts were made of materials quite unsuitable for the purpose.

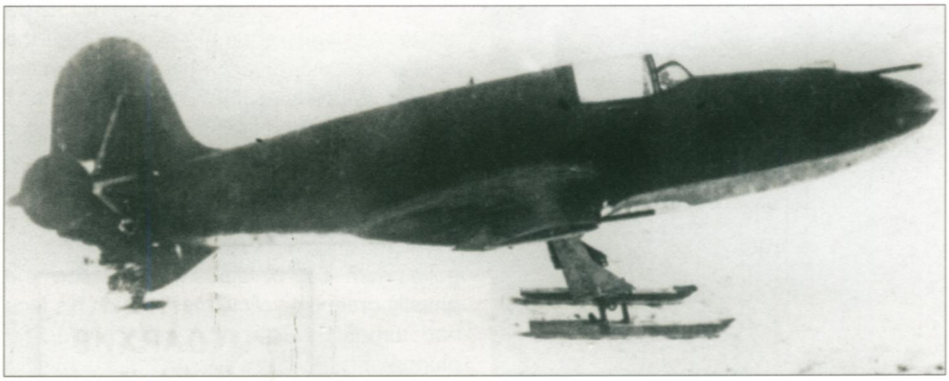
Bench tests of the rocket motor began in September; for this purpose a special test bench resembling a fuselage was built. When nitric acid was injected into the combustion chamber, it produced brownish fumes. A bucket was placed under the motor, the acid flowed into it, and mechanics wearing gas masks carried it to the scales to measure the weight and to determine the consumption of the propellant per second – a truly infernal job!

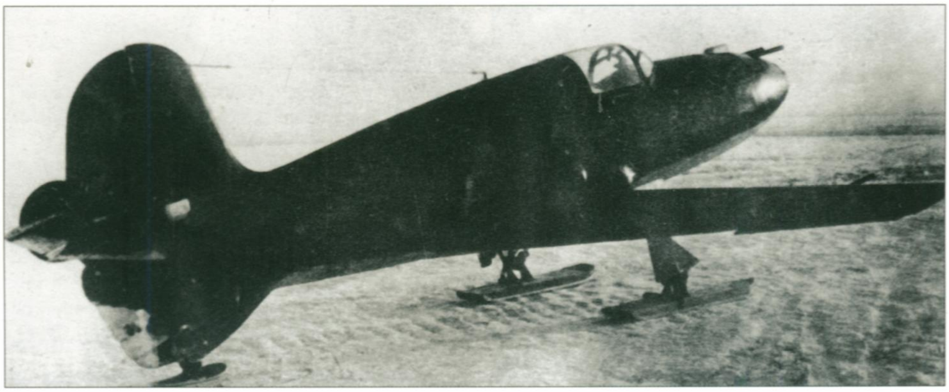
Nevertheless, in a month plus ten days instead of five, the completed machine was rolled out. Boris Koodrin, the appointed test pilot, had fallen ill and was replaced by Grigoriy Bakhchivandzhi. After graduating from the Orenburg aviation school Gosha, as his friends called him, had flown the I-5, I-15 and I-16 fighters. From the very first days of the war he joined combat at the front. […] In the autumn he was recalled to the rear for testing "a secret aircraft".'

The first encounter with the test pilot became a memorable occasion for the designers. Bakhchivandzhi asked few questions, preferring to listen. Before taking his leave he said: 'Just one request: to avoid distracting you, I would like to get acquainted with the whole thing in the process of the work; after all, I was a mechanic previously'. Later on he spent whole days in the workshops and at the test bench, taking part in the work and studying closely both the motor and the aircraft.

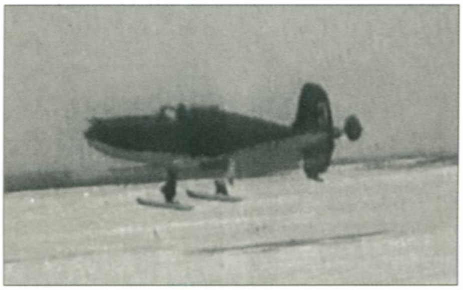
In February the rocket motors delivered to the plant commenced testing on the test bench built at the premises. A. V. Pallo performed the first three runs of the motor with a brief transition to full power. Bakhchivandzhi was close at hand, to the left of the test cabin,

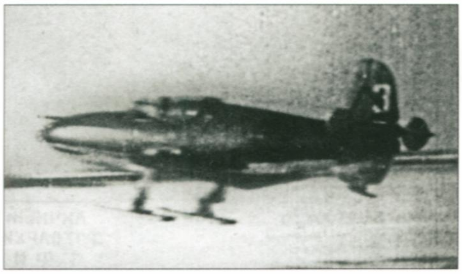






Above right, centre right and right: This uncoded BI (possibly the third prototype) fitted with skis features both the envisaged armament note the protruding barrels of the ShVAK cannons) and a gun camera installed in a fairing aft of the cannons. The lower tailplane bracing struts are visible here.





Top left: The third prototype (BI No.3, '3 White') is readied for a test flight on a snow-covered airfield.

Second from top: The BI No.3 becomes airborne, belching a jet of flame.

Centre and above centre: The third prototype as it glides to a safe (and fast) landing.

Left and above left: Stills from a cine film capturing the fatal crash of the BI No.3 on 27th March 1943 as it enters the death dive (above left) and immediately before the impact.

watching Pallo's actions closely and listening to his explanations.

On 20th February the pilot climbed into the cabin of the test rig, calmly and confidently checked the voltage of the electric circuit, raised the pressure in the tanks, vented the fuel, then switched on the igniters and effected the start-up injection of fuel, using the throttle lever. The rocket motor went into start-up mode; an even, subdued noise was heard, produced by the combustion of the start-up fuel. Then, as a signal light illuminated, Bakhchivandzhi advanced the throttle (which had been locked up to that moment) to switch on the main fuel feed. The motor went to full power; three or four seconds later an explosion occurred. At the moment of the explosion the motor head tore away from its attachments, flew between the nitric acid tanks, smashed against the armoured back of the pilot's seat and broke the attachment bolts; Bakhchivandzhi was thrown forward, hitting his head against the instrument panel. The pilot nevertheless managed to retard the throttle, shutting the fuel valves, but the runaway motor head had ruptured the oxidiser pipelines. A jet of nitric acid poured on Pallo's face and clothing. Everything was enveloped in acid fumes. The nozzle unit of the motor was hurled far away to the frozen water reservoir covered with snow.

Pallo was on the point of dashing out through a side door, but then realised that Bakhchivandzhi was still in the cabin of the test stand. Pallo stretched out his hand in the direction of the cabin, groping for the pilot, felt the fur collar of Bakhchivandzhi's leather jacket, grabbed it and pulled as hard as he could; then he pushed the pilot through the front entrance gate of the shed. Once on the outside, the mechanics of the test stand took charge and started laving Pallo's face with a sodium bicarbonate solution. Pallo took a deep breath of fresh air, felt the skin of his face burning acutely and plunged his head into a snowdrift. The pain subsided. The mechanics pulled him out of the snowdrift, saw the ghastly greenish-yellow mask which his face had turned into because of the acid and plunged his head into a tank with the sodium bicarbonate solution. All this took place in the course of a few minutes. Then the OKB leaders appeared on the scene, and the injured persons were whisked away to a hospital situated in a nearby house. Only there, somewhat later, did Pallo understand what terrible danger he had avoided by donning protective glasses at the last moment.

Above: Viktor F. Bolkhovitinov signs one of the BI's test reports or a test flight assignment.

The accident investigation board came to the conclusion that the combustion chamber had suffered a fatigue failure under the influence of intercrystalline corrosion because the motor's service life had long expired. Only two rocket motors had been built; one of them was used for adjustment trials, the other being intended for installation in the aircraft.

Memoirs written by Pallo himself and published many years later give an idea of the dangers and difficulties which had to be surmounted by the testers and designers of the aircraft at that time. The accident during the bench tests of the motor left terrible scars on his face which he retained for the rest of his life. Here is an excerpt from his memoirs:

'Before that I had started up the motor on the test bench myself three times or so. There had been nothing untoward. Bakhchivandzhi was standing by my side, watching my actions. Then he climbed into the cabin and I stood beside him. He performed the starting procedure, which proceeded normally; the motor was entering the normal thrust mode… and then came the explosion. The motor disintegrated, the nozzle unit was thrown far away to a snow-covered pond, the combustion chamber struck the reservoirs, the front part of the motor hit the back of the pilot's seat and broke the attachment bolts; Bakhchivandzhi hit his head on the front hook of the dynamometer measuring the thrust, and I was doused with the acid which was streaming in jets under pressure from the damaged piping.'

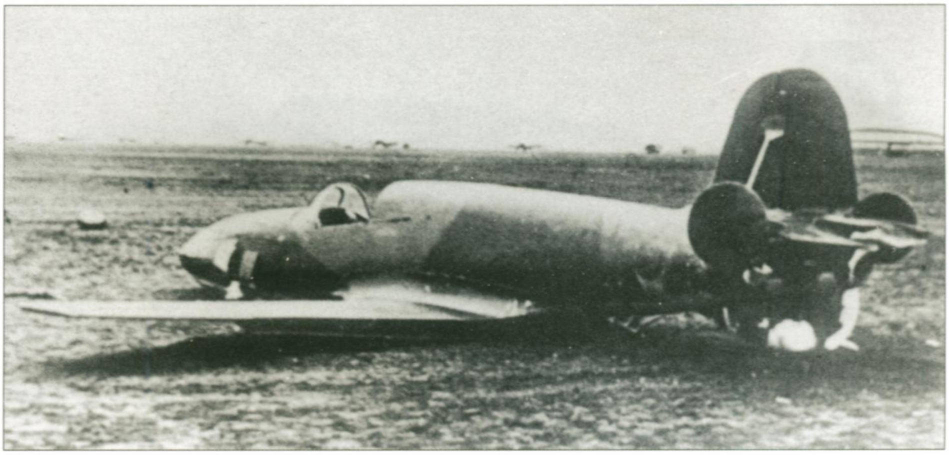
Here it should be noted that in the spring of 1942 the engineers of NII-3 (the institute where the rocket engine was developed) started work on their own project of an interceptor with a composite powerplant comprising a twin-chamber liquid-fuel rocket motor with turbo pump fuel feed – the first of the kind

Above: Test pilot Boris N. Koodrin, who was the BI's project test pilot before Bakhchivandzhi – and after Bakhchivandzhi's death.

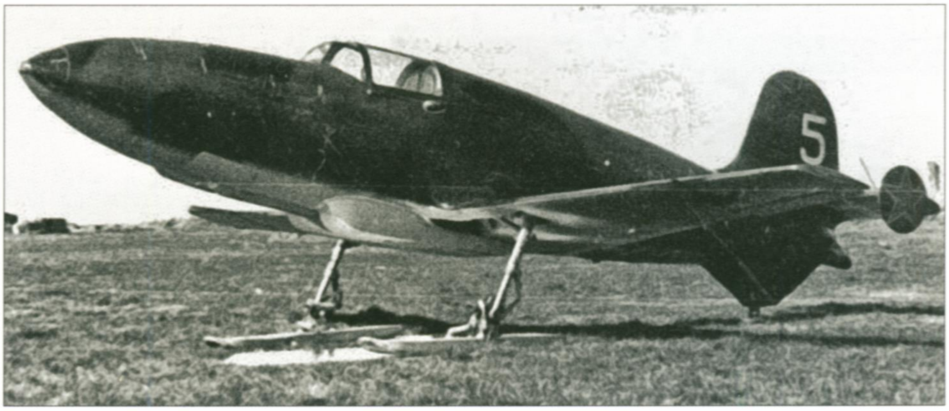
in the USSR – and two ramjets (aircraft '302'; see Chapter 2). Therefore Dooshkin's group sort of lost interest towards the development of a rocket motor intended for the BI fighter.

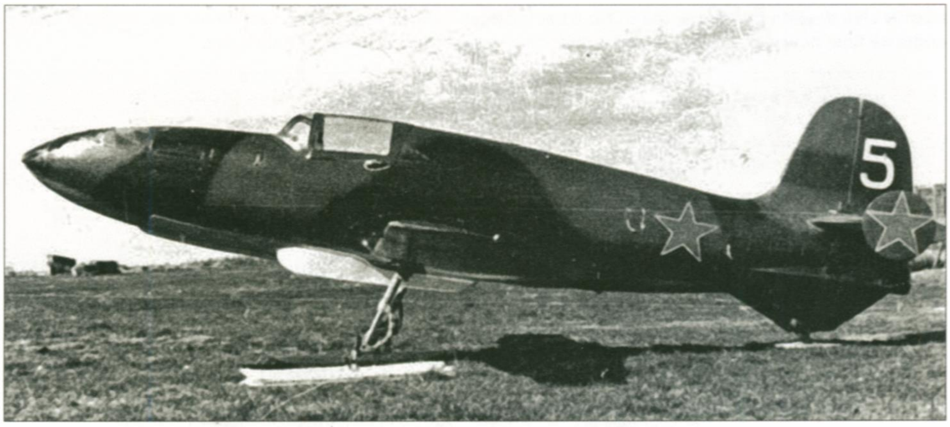
In March 1942 the test bench was rebuilt and alterations were made to the rocket motor's fuel feed system. After the accident everybody feared that Bakhchivandzhi would refuse to participate in further tests (he had seriously injured his forehead and sustained acid burns), but, on the contrary, his conviction that the work should continue became even stronger. On the flight-cleared example of the motor check-up hydraulic tests were made followed by 14 firing tests, of which three were conducted by Bakhchivandzhi. On 25th April 1942 NII VVS issued order No.701 calling for the testing of the BI at Sverdlovsk. On the same day the first prototype BI was transported from Bilimbai to Kol'tsovo airfield where NII VVS had taken up residence after the evacuation (the place later became the city's main airport). On 30th April two check-up firings of the motor were made (the first of them was performed by Pallo, the other one by Bakhchivandzhi). Preparations for the flight tests got under way. At first the firing tests were conducted on the ground, then, on 2nd May, the fighter started making high-speed runs; this was preceded by repairs to the undercarriage. During the runs the aircraft became airborne and flew 50 m (160 ft) at a height of 1 m (3 ft).

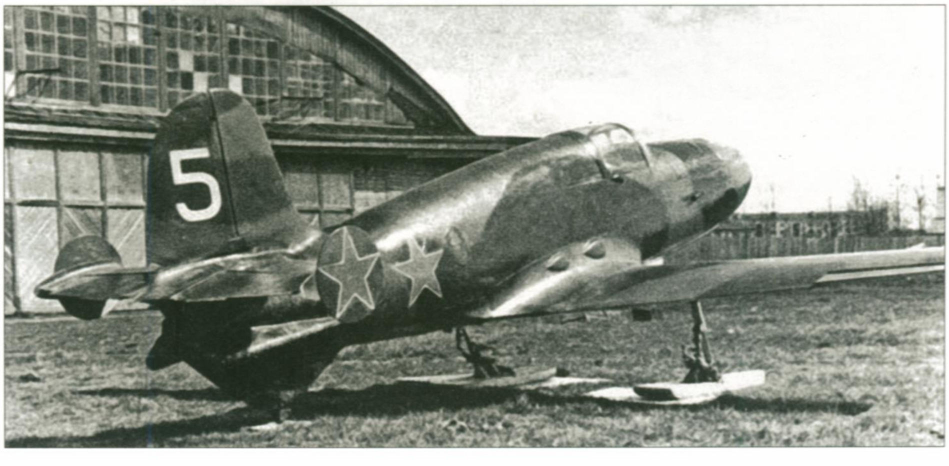
On 15th May all vehicles were removed from the airfield and the first prototype BI fighter was delivered to the holding position on the runway. Since the thrust of the rocket motor could be altered only by an insignificant margin, the aircraft could not taxi to the



Above: One of the BI prototypes after shearing off its undercarriage in a landing accident. Damage to the forward fuselage is also evident. Note the jettisoned cockpit canopy.







The fifth prototype (BI No.5) with fairings for the retracted skis. Oddly, the fighter is still on skis, though the snow's gone. Note the strakes on the rear fuselage and the star insignia repeated on the endplate fins.

runway on its own; it had to be towed and oriented in the direction of the take-off with the help of a tractor.

For the maiden flight of the new rocket-propelled interceptor (sometimes the first prototype was referred to as the BI-1) a State Commission was set up; it was presided by V. S. Pyshnov. The commission also included the leader of OKB-293 V. F. Bolkhovitinov, chief of NII VVS M. I. Tarakanovskiy and project engineer for the rocket motor A. V. Pallo. NII VVS test pilot G. Ya Bakhchivandzhi was appointed project test pilot.

L. S. Dooshkin duly recorded in his diary the final preparations for the flight:

'25th April. A session of the Commission. Work with the documents.

26th April. Examination of the airfield and the adjoining area.

27th-29th April. Inspection of the aircraft and the motor.

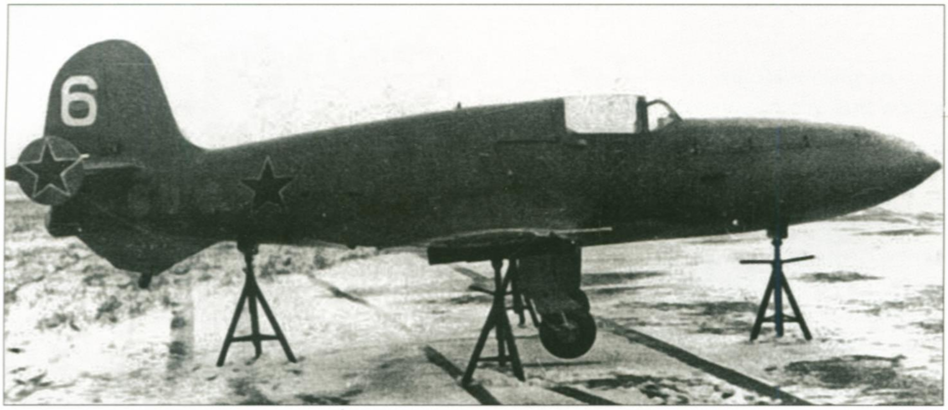
30th April. Firing test of the motor installed in the aircraft, accompanied by controlling the operational mode.

1st May. Filling the aircraft's tank with the fuel for the rocket motor.

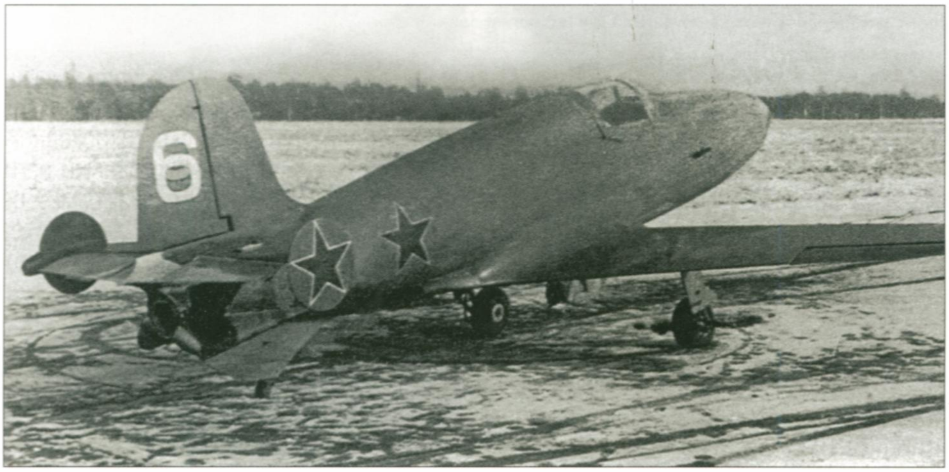
2nd May. Check-up taxiing of the aircraft on the airfield with motor turned on. Time: 20 h 30 min.

3rd May. Check up of the sealing of fuel tanks and piping.

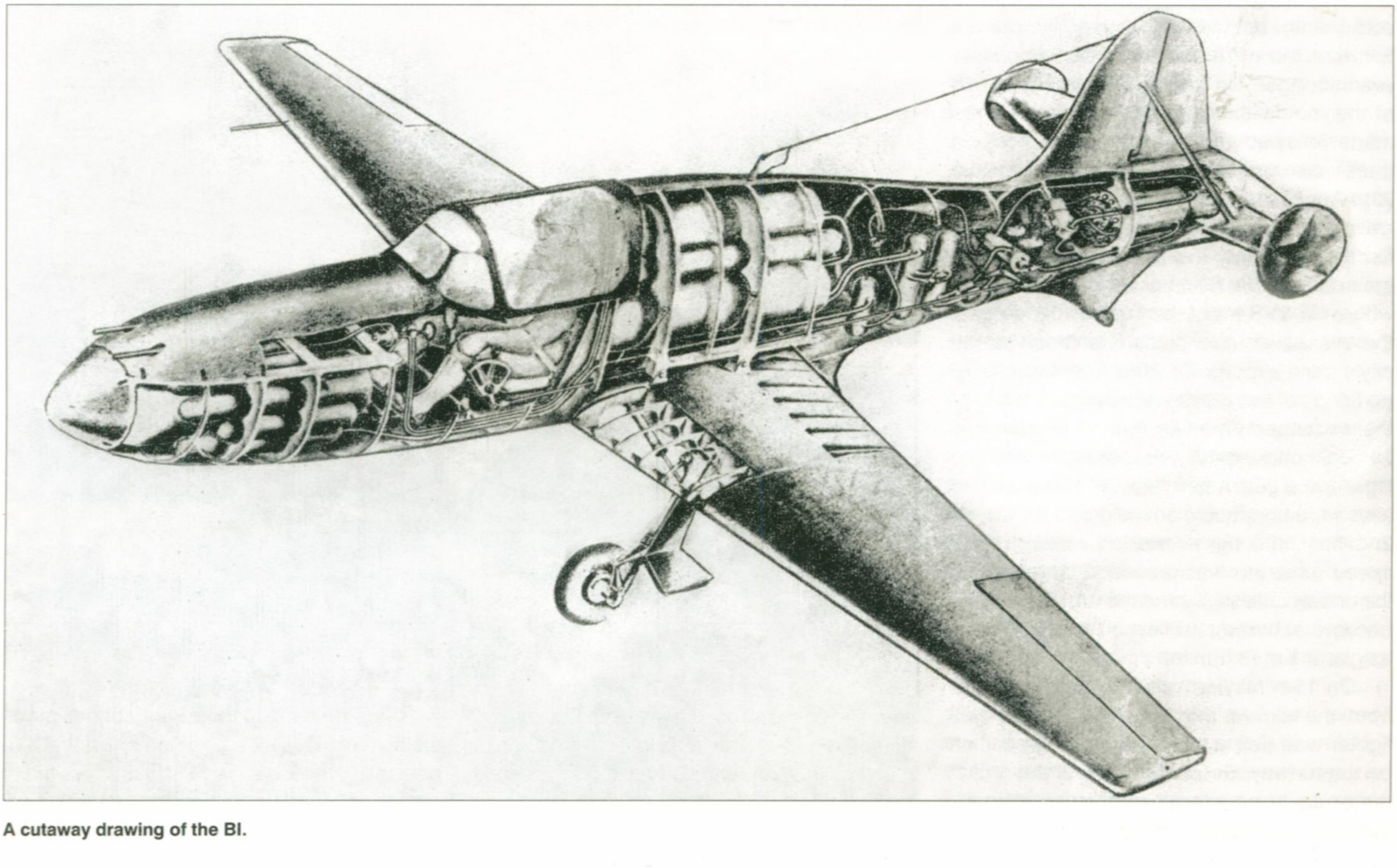
4th-7th May. Modifications to the aircraft and the powerplant according to the recommendations of the commission (inspection



Above: '6 White', the sixth prototype (BI No.6), trestled for landing gear retraction tests. This photo shows the machine as originally built.



Above: Like the fifth prototype, the BI No.6 had splayed ventral strakes and carried red star insignia on the endplate fins; however, it was painted a uniform green colour on the upper surfaces.



A cutaway drawing of the BI.

hatches, installation of protective shields against the nitric acid and so on).

8th-11th May. Bad weather, no ground work possible.

12th May. Packing the runway surface.

13th May. The aircraft with the motor running makes a short hop on the airfield.

14th May. A session of the Commission for preparing the flight mission.

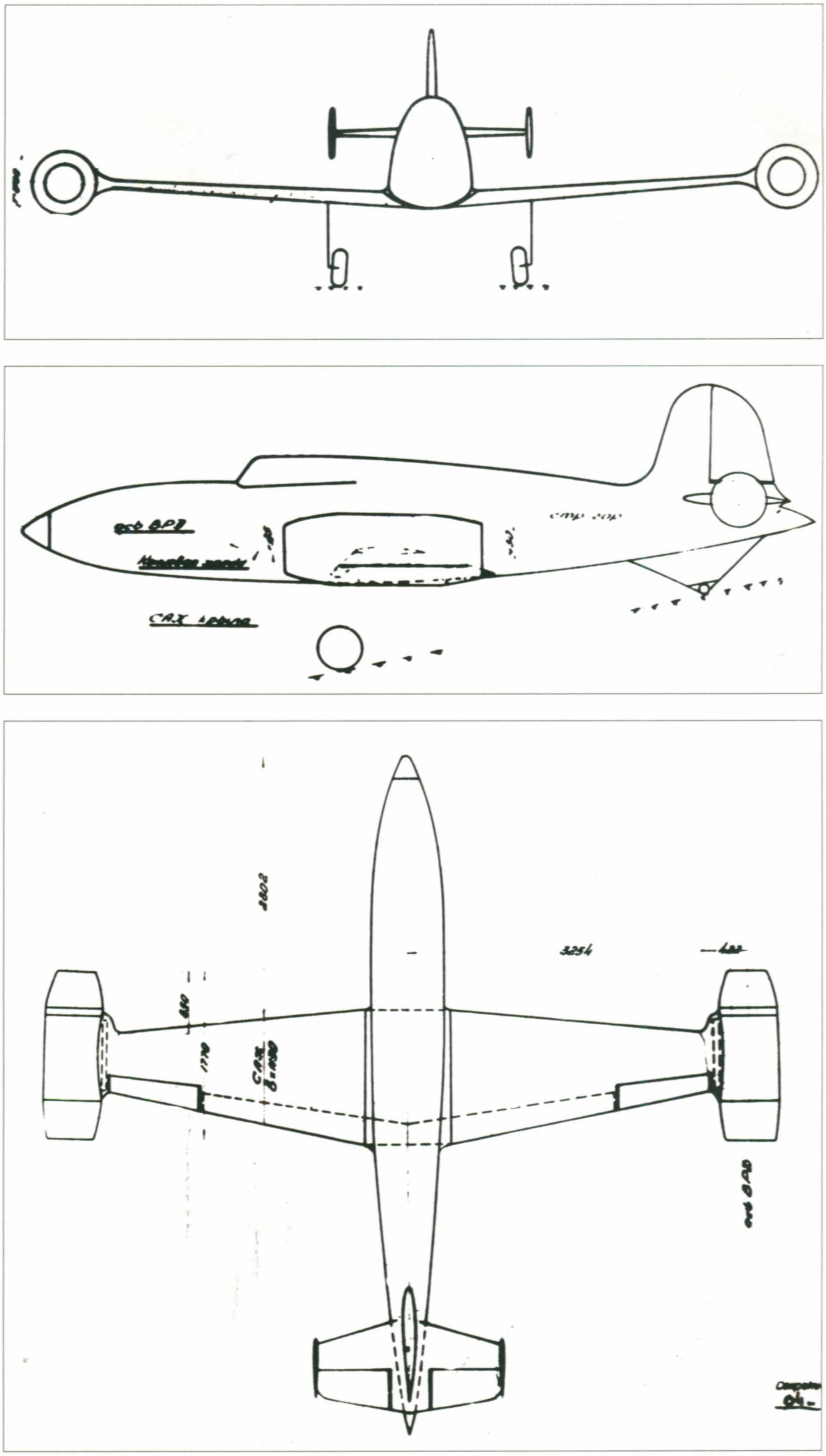
15th May. The first flight of the BI-1. Time 19 hours.'

Grigoriy Ya. Bakhchivandzhi performed the first flight in the BI No.1 on 15th May 1942. The all-up weight of the aircraft in that flight was limited to 1,300 kg (2,865 lb), the motor was adjusted for a thrust of 800 kgp (1,760 lbst). The flight was to take place at noon, but bad weather forced a delay until about 5 o'clock in the afternoon. Bakhchivandzhi and NII VVS test pilot P. I. Fyodorov flew a weather reconnaissance mission in a Polikarpov U-2 utility biplane. This is how L. S. Dooshkin recalled the portentous day of the first flight of the first Soviet jet aircraft:

'At last, the work on the aircraft had been successfully completed and the commission gave the go-ahead for the first flight. On 15th May 1942 the situation on the airfield was unusual. Other aircraft parked on the runway were removed. Their flights were suspended. A great number of representatives of civil and military organisations came to the airfield. The weather was cloudy. We had to wait for a long time until the sky above the airfield cleared; that was necessary for visually observing the flight of the BI aircraft. There were no other means of monitoring the flight: neither radio, nor telemetry.

Test pilot G. Ya. Bakhchivandzhi was in cheerful, good spirits. His only complaint was about the clouds in the sky and the long time of waiting for the take-off clearance. At last, by 18 o'clock the sky had cleared. Permission for the take-off was granted. The aircraft was towed to the place where it would begin its take-off run.'

The pilot had arrived at the airfield for this flight, wearing a new leather coat and in shiny box-calf high boots; however, when he boarded the aircraft before receiving the command to take off, he was clad in an old flying jacket and old boots. When asked why he had changed his clothes, Bakhchivandzhi answered that the new coat and high boots might be useful for his wife (she might sell them if he crashed – *Auth.*), and the well-worn clothes would not prevent him from fulfilling the mission. After that he took up his place in the cockpit. An unusual command rang out: 'Stand clear of the tail!' (When a piston-engined aircraft started up, one would usually hear the command: 'Stand clear of the prop!') A blinding torch of fire belched from the nozzle, and the machine literally leaped into the sky. The thunderous roar of the ignited engine had rolled over the airfield for less than a minute, and the aircraft had already turned into a shiny dot at an altitude of 1.5 km (some 4,900 ft).



Three views of the BI No.6 as it would have looked with wingtip-mounted ramjet cruise engines.

After the ignition the motor almost immediately delivered the maximum thrust that had been adjusted in advance. It was at this thrust rating that the take-off run, climb and subsequent manoeuvres were performed. If it was necessary to limit the speed in flight, the pilot could do this only by climbing. Making the break to land, performing the flareout and landing was only possible with the motor shut down, using the altitude and speed attained during the 'active' phase of the flight. Naturally, all this had to be performed with utmost precision because it was virtually impossible to correct a deviation from the desired course.

After the motor had run the calculated time, Bakhchivandzhi steered the machine towards its first landing. Seconds after the touch-down, one of the undercarriage legs collapsed and the aircraft swung. The disconcerted pilot tried to explain something to Bolkhovitinov who had come to the aircraft, but the Chief Designer just hugged the pilot in his arms. Designers, engineers, workers who had gathered around the aircraft also hugged and kissed one another. There were no pompous speeches, although everyone realised they had witnessed the birth of a radically new kind of aviation – jet aviation.

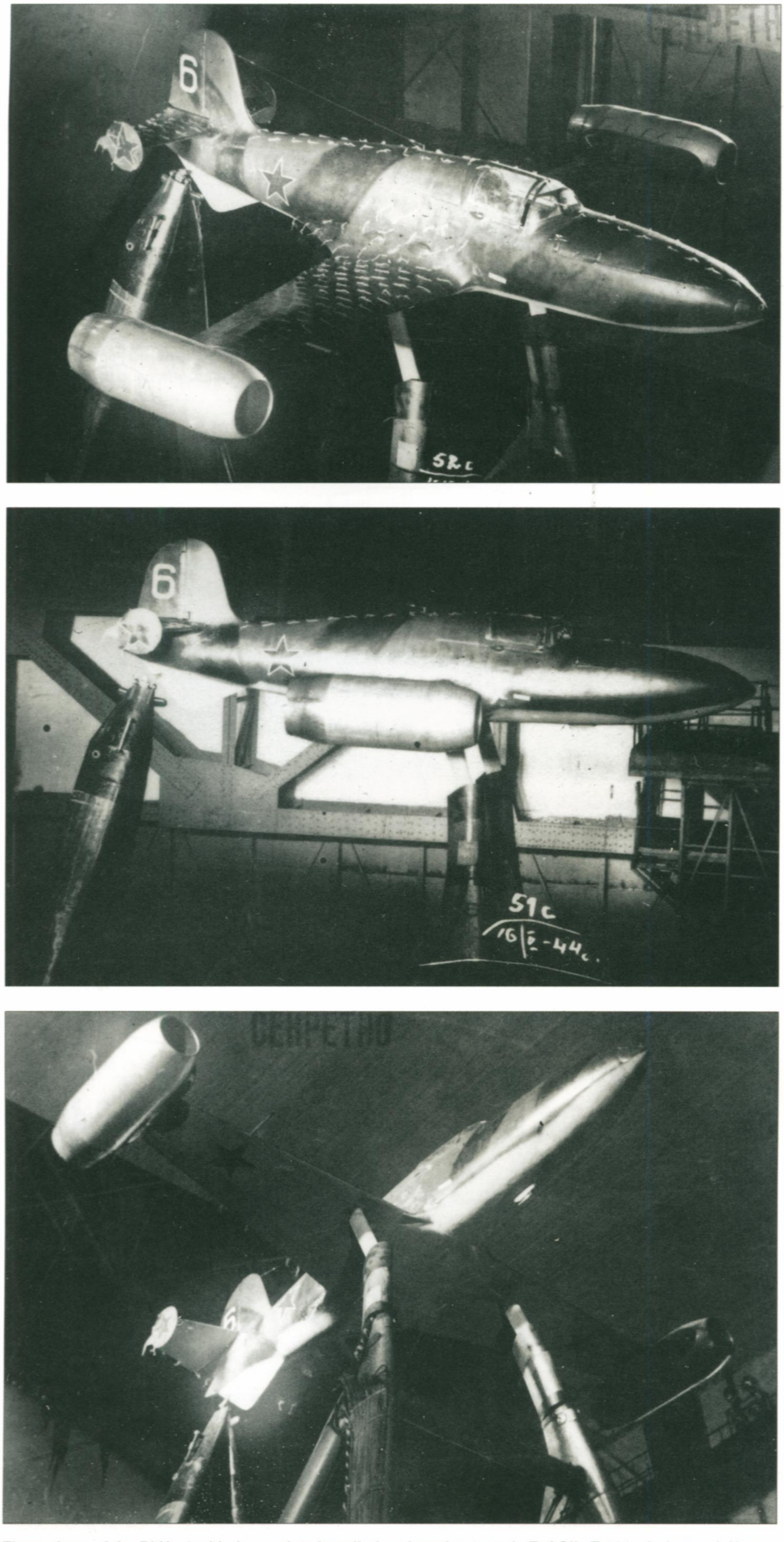
Here is an eyewitness account of that flight:

'The rocket aircraft was confidently charting a curve in the sky... The last pre-calculated landing approach manoeuvre was completed. The dock-tailed aircraft touched down near the landing sign... The world's first flight of a rocket aircraft had been accomplished! All those present rushed to the machine. They began in concert to throw the pilot, red-faced with happiness, into the air... Grigoriy Yakovlevich was full of elation.'

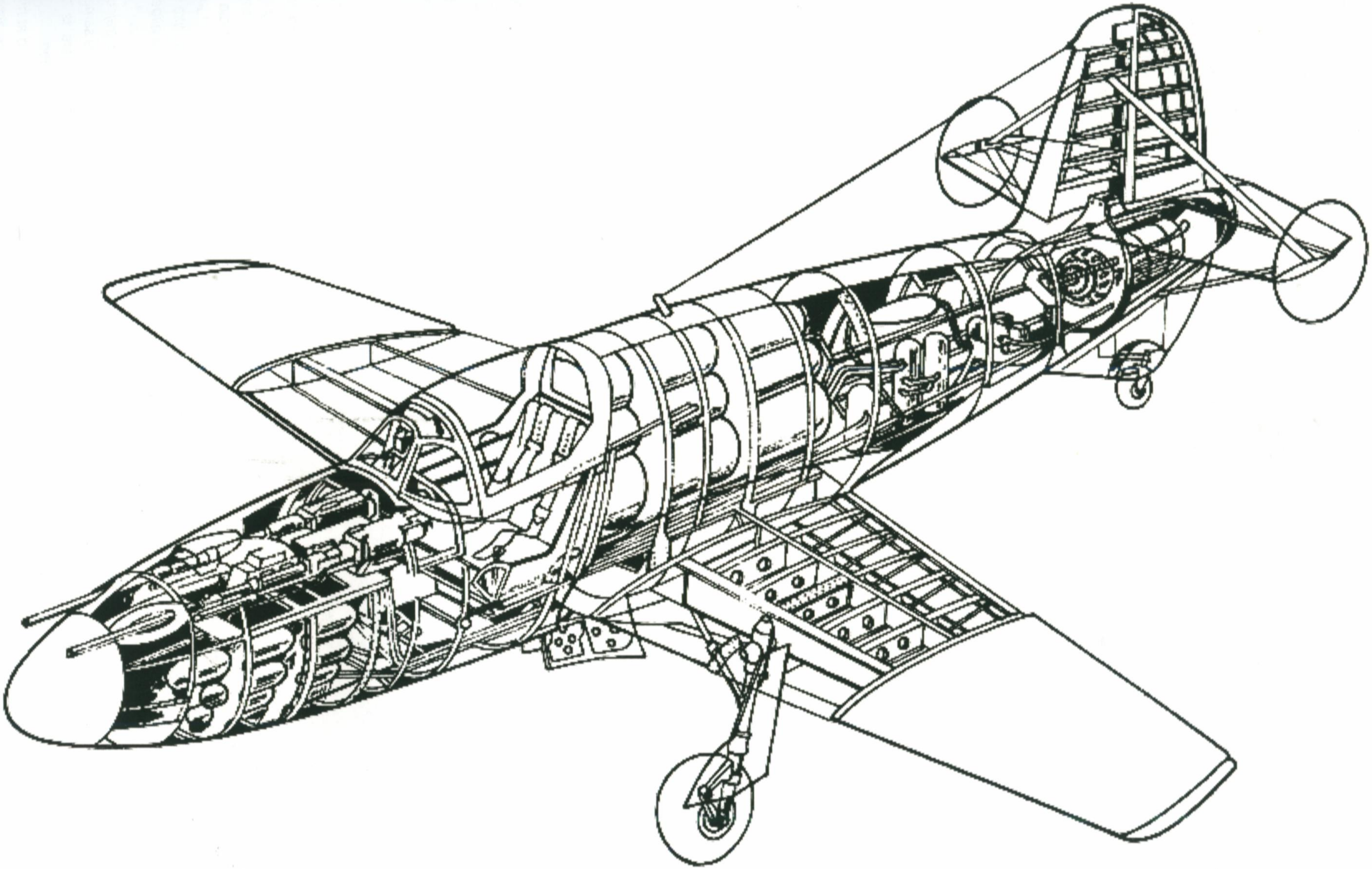
The flight lasted exactly 3 minutes 9 seconds. The data recorders showed that the aircraft had attained a maximum altitude of 840 m (2,755 ft), a speed of 360 km/h (224 mph) and a climb rate of 23 m/sec (4,528 ft/min). The rocket motor ran for exactly 66 seconds. On 18th May Captain Bakhchivandzhi signed the 'Conclusion on the first flight of the BI-1 aircraft with the D-1-A-110 engine'. Here is an excerpt from the document:

'The engine fired up on the third injection of the start-up propellants; the transition to maximum thrust proceeded normally. The engine operation on take-off and in the air was also normal. The engine was shut down when the engine overheating warning light came on. An abrupt shutdown of the engine did not affect the aircraft (that is, it did not cause a deviation in any direction – *Auth.*). *The pilot experiences a deceleration, like on a conventional aircraft. The BI-1 as a glider is very similar in its handling to the Yak-1 aircraft. The take-off, lift-off and climb trajectory maintenance are performed in the same way as on a conventional aircraft, there is no tendency towards yawing and rolling.*

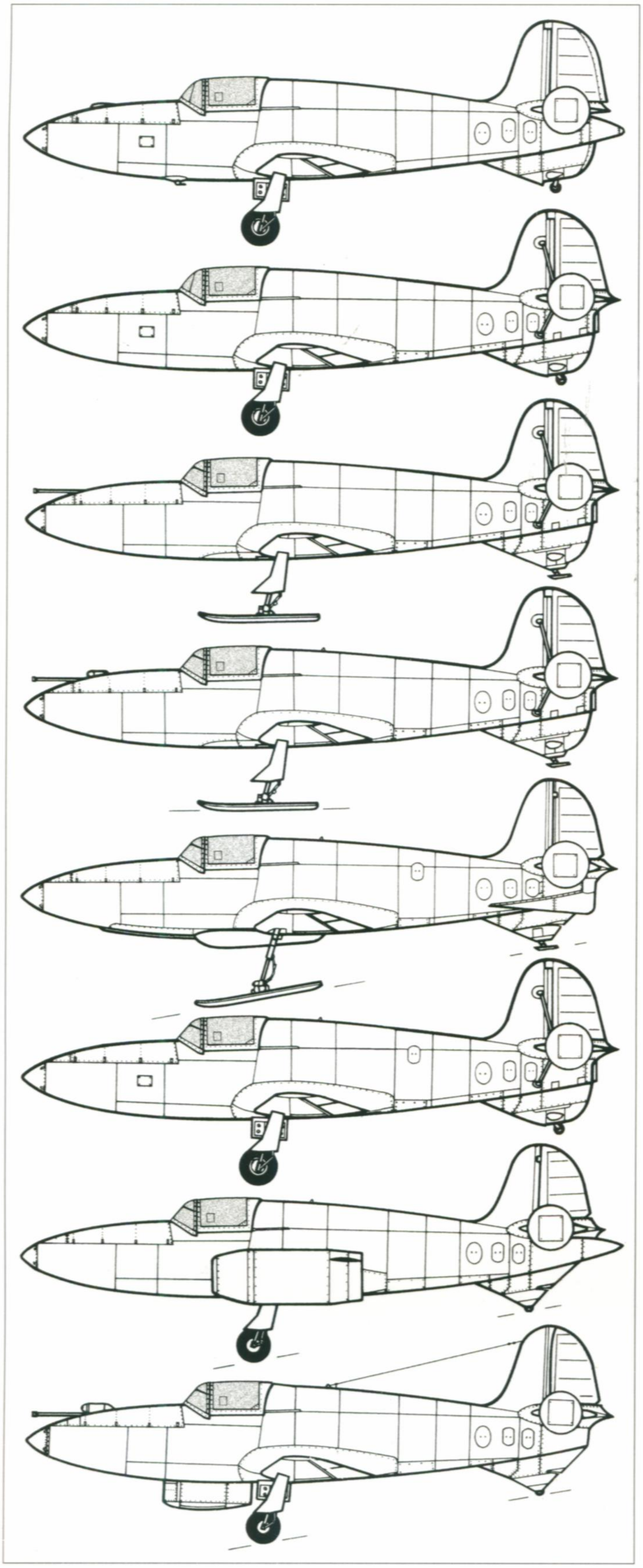
The climb is performed at higher speeds and at a steeper angle. The aircraft performs turns without lowering the nose or pitching up,

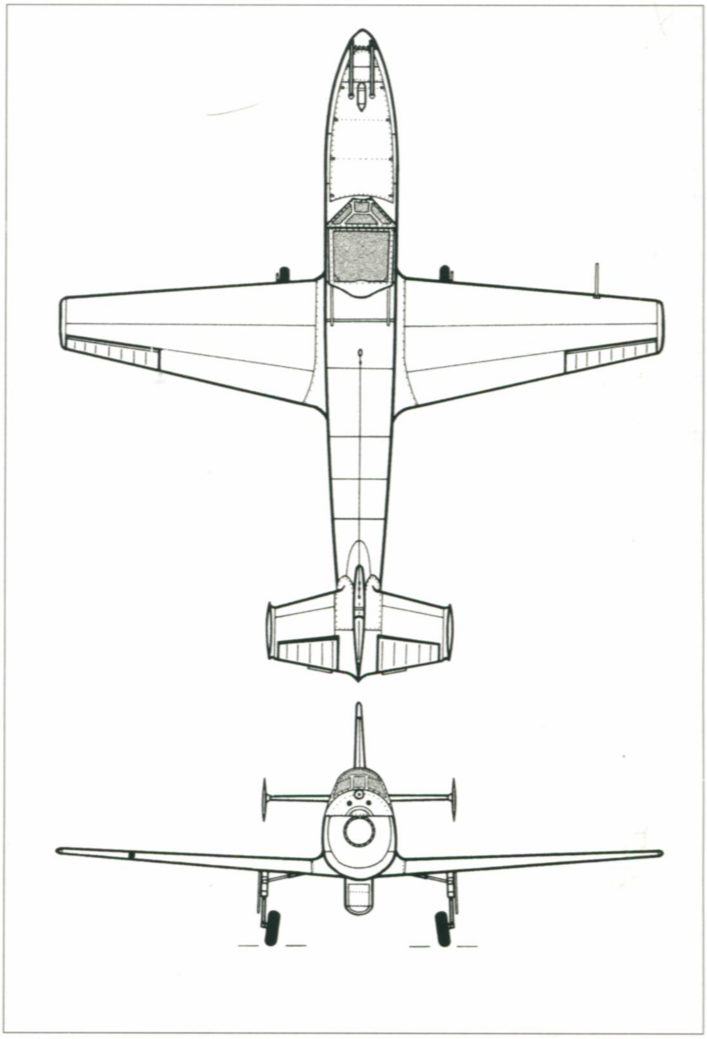


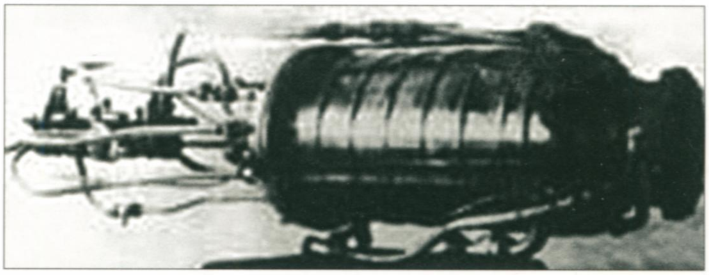
Three views of the BI No.6 with the ramjets installed undergoing tests in TsAGI's T-101 wind tunnel. Note the wool tufts, the fairing closing the rocket motor nozzle and the addition of black camouflage spots.

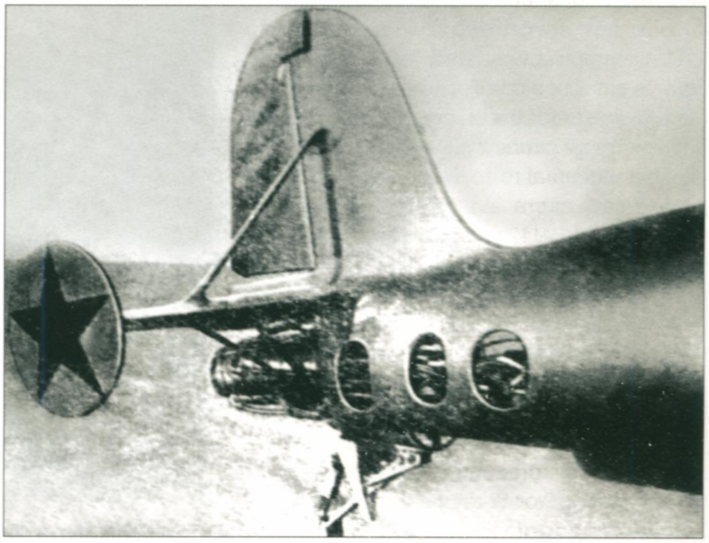


A cutaway drawing of the BI.









Above, top to bottom: BI No.1 in engineless configuration; BI No.1 with the rocket motor fitted; BI No.2; BI No.3; BI No.5; BI No.6 as originally built; BI No.6 with ramjet engines fitted; and a BI-VS with a bomb cassette fitted.
Top right: Upper and front views of the BI-VS.
Above right: The D-1A-1100 rocket motor.
Right: The BI's rear fuselage with the cowling and access panels removed.

the stick needs to be pulled in conformity with the steepness of the turn; there are no vibrations.

The aircraft glides and performs side-slips in a stable fashion, like a conventional aircraft. Gliding with the flaps deployed requires a high angle of descent which is maintained by the aircraft of its own accord (there is a slight pulling force on the stick). The landing needs to be performed with a sufficient speed margin because a landing at insufficiently high speed causes the aircraft to sink rapidly, and this cannot be countered even by pulling the stick. The landing was performed at insufficient speed, with an undercarriage failure as a result.

Flying this type of aircraft, in comparison with conventional types of aircraft, is extremely pleasant because the pilot has in front of him no propeller, engine, noise and exhaust gases which enter the cockpit. The pilot sits in the nose of the aircraft, enjoying an exceptionally good view of the forward hemisphere and a view of the rear hemisphere which is appreciably better than on a conventional aircraft. The arrangement of instruments on the panel is well-chosen, they are easily readable, the cockpit does not have an excessive number of devices; the control levers of various units are located conveniently. Theoretical calculations for this aircraft have been fully corroborated by the flight – within the flight modes performed. The aircraft has a good stability and manoeuvrability at speeds up to 360 km/h [223 mph].

As regards ease of handling, the aircraft is superior to contemporary fighters.'

The Report on the flight was prepared between 16th and 20th May. The success was so impressive that the State commission gave a highly positive assessment of the results and prospects of the work.

'The take-off and flight of the BI-1 aircraft with a rocket motor used for the first time as the aircraft's main engine has proved the practical feasibility of flight based on a new principle; this opens up a new direction in the development of aviation.'

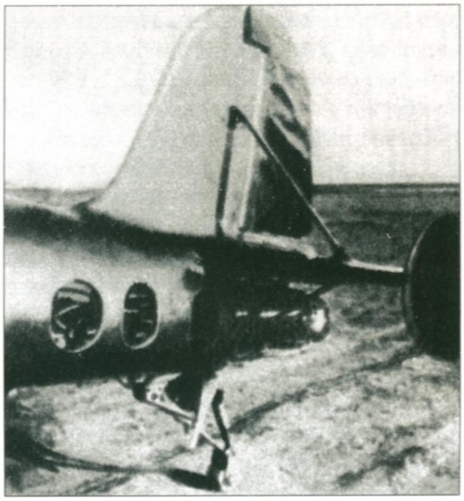
This was the world's first-ever flight of a fighter with a liquid-fuel rocket motor specifically designed for the purpose of intercepting high-altitude bombers. In other countries, only experimental rocket-propelled (or turbojet-powered) aircraft without armament were flying by May 1942 – these were the British Gloster G.40 and the German Heinkel He 176 and DFS-194 (the precursor of the Messerschmitt Me 163 Komet rocket-propelled fighter).

Due to the deterioration of the first prototype's airframe structure (primarily caused by the nitric acid vapours) subsequent flight testing of the BI aircraft was conducted on the second (BI No.2 or BI-2) and third (BI No.3 or BI-3) prototypes of the fighter. These differed from the first prototype mainly in being fitted with a ski undercarriage. At the same time a decision was taken to build a small batch of BI-VS aircraft for service tests (VS stands for *voyskovaya seriya* – service-test batch). At the suggestion of Il'ya F. Florov, endplate fins were installed at the prototypes' stabiliser tips after the construction of the first prototype, in the course of aerodynamic research and after the beginning of flight tests.

The pre-production BI-VS aircraft differed from the prototypes in armament: in addition to two nose-mounted cannons, a faired bomb cassette was installed under the fuselage along the centreline ahead of the cockpit. The cassette accommodated ten small bombs weighing 2.5 kg (5.5 lb) apiece and having a high explosive power. The assumption was that these bombs would be dropped over enemy bombers flying in close formations and would inflict damage to them both by the shock wave and by splinters.

In January 1943 a document was prepared on the completion of ground tests of the second prototype, the BI No.2 (BI-2), aptly serialled '2 White'. The flights of this aircraft took place on 10th and 12th January; on its maiden flight the BI-2 was piloted by G. Ya. Bakhchivandzhi, and on the second occasion NII VVS test pilot K. A. Groozdev was at the controls. After that, on 14th January, deputy chief of NKAP's 7th Main Directorate Alekseyev reported to People's Commissar A. I. Shakhoorin in his letter No.149:

'I hereby report that, according to information from Bolkhovitinov, on 10th January a jet-powered interceptor performed a flight which lasted 4 minutes, including the time of the take-off and landing run.



Above: Another view of the BI with the rocket motor exposed for inspection. Note that the normally faired tailwheel strut is also exposed.

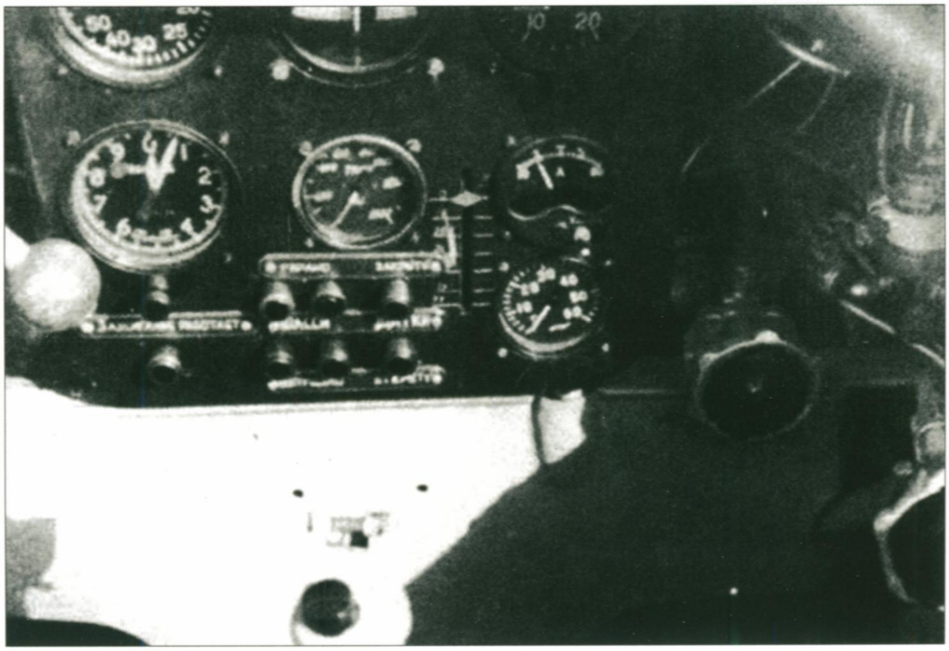
The engine was running for 63 seconds. The thrust was 700-800 kg [1,540-1,760 lbst], the flight altitude was 1,100 m [3,610 ft].

In order to check the vibrations which had arisen in the first flight with the undercarriage extended, the speed of flight was limited to 400 km/h [249 mph].

During the flight the undercarriage was retracted and no vibrations were observed.

The gliding descent and landing, as well as the flight as a whole, were performed by Captain Bakhchivandzhi in an exemplary fashion. After the flight the technical condition of the aircraft was assessed as satisfactory'.

On 12th January in a flight performed by Groozdev one of the skis broke away as the landing gear extended, but the pilot managed a safe landing. A. V. Pallo quotes in his memoirs a colourful comment made by Groozdev



Even by the day's standards the BI's instrument panel was simple and uncluttered.

after a flight on the BI No.2: 'It's fast, it's scary, and it really pushes you in the back. You feel like a devil riding a broom.'

Flying a rocket-propelled interceptor was really very difficult, and not only because it was unusual. The aircraft could land only after the fuel had been used up (otherwise there was a danger of explosion during the landing). Sitting right next to a lot of nitric acid stored in a tank under high pressure was also unpleasant; added to which, sometimes the acid seeped through the piping joints or ate through the walls of pipes and tanks. This kind of damage had to be rectified incessantly, which caused considerable delays in flights conducted throughout the winter of 1942-43.

V. P. Mishin, a participant of those events who went on to become an outstanding Soviet designer of space vehicles, made an interesting remark about the safety measures during the work on the liquid-fuel rocket motors – or, more exactly, about the complete absence of such measures. The nitric acid for the rocket motors was supplied to Kol'tsovo airfield in big glass bottles. From the bottles it was poured – without the use of protective gloves – into containers from which it was later transferred to the fighter's tanks.

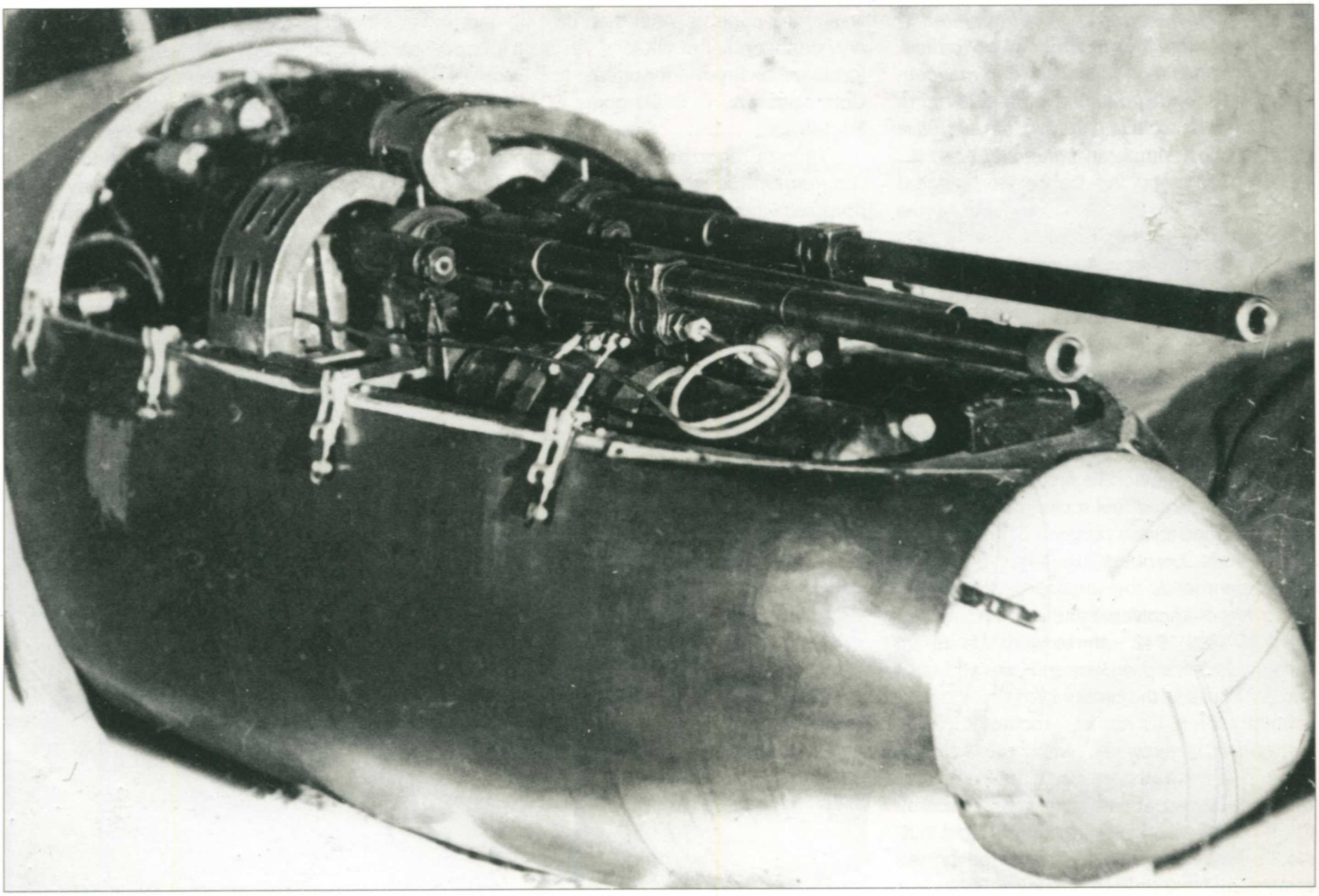
On 11th March 1943 the fourth flight of the ski-equipped BI No.1 (BI-1) took place, followed on 14th March by the fifth flight of the BI-1 on skis (flown by Bakhchivandzhi). The amount of fuel in the tanks varied from 315 to 498 kg (695-1,098 lb). Although the day's flight mission stipulated the attainment of a speed of 750-800 km/h (465-196 mph), the skis failed to retract, and the flight had to be fulfilled in accordance with the previous mission task. The take-off thrust was raised to 1,100 kg (2,425 lb), the climb was performed at a speed of 480 km/h (298 mph). At an altitude of 2,800 m (9,180 ft) the rocket motor cut, the pilot succeeded in climbing to 3,200 m (10,500 ft). The flight lasted 6 minutes 13 seconds; the motor ran for 80 seconds.

In March 1943 the Act on the completion of ground tests of the BI No.3 (BI-3, serialled '3 White') was prepared; it confirmed that the machine was ready for joint tests. On 21st March Bakhchivandzhi performed the sixth flight of the BI-3 (again on skis).

The mission task for the seventh flight, which took place on 27th March 1943, envisaged the attainment of an airspeed of 750-800 km/h in level flight at 2,000 m (6,560 ft), with an engine thrust of 1,100 kgp (2,425 lbst). The amount of propellants in the tanks was 497 kg (1,096 lb). The BI No.3 easily lifted off the runway, climbed to altitude and transitioned to level flight. After the automatic shutdown of the motor, which had been in operation for 27 seconds in that flight, nothing foreboded trouble. All of a sudden the aircraft, which was flying horizontally, lowered its nose, entered a dive and plunged into a frozen lake near a small village, impacting at an angle of about 50°. The villagers saw a tower of black smoke – that was the nitric acid burning. Everything that could give some clue to what had happened was smashed completely. The flight had lasted 6 minutes and 42 seconds.

At that time the accident investigation board proved unable to determine the real reason that had caused the fighter to enter the death dive. In its report the board noted that phenomena taking place at speeds of 800-1,000 km/h (496-621 mph) had not yet been explored. In the opinion of the 'tin kickers', these speeds could be accompanied by new factors influencing the controllability, stability and control forces; these factors might diverge with the current notions and, in consequence, might fail to be taken into account.

The testing of the BI No.2 and BI No.3 was formally presented as the 'Joint State and



The BI's cannon bay with the cowling removed, showing the twin 20-mm ShVAK cannons and their ammunition boxes.

Factory Testing of the BI interceptor designed by Bolkhovitinov and manufactured by plant No.293, with the D-1A-110 liquid-fuel rocket motor designed at NII-3'.

In the 'Report on the work of plant No.293 in 1942', which was sent to NKAP in 1943, mention is made of several work programmes, including the BI fighter's development programme. The report lists the employees who had earned distinction in this work. These include Il'ya F. Florov, the deputy chief designer who directed the design work on the aircraft and the calculations; Aleksey M. Isayev – the leading engineer who developed the fuel system for the rocket motor; Aleksandr Ya. Bereznyak – the leading engineer who developed the aircraft's airframe, and Grigoriy Ya. Bakhchivandzhi – the pilot. With respect to the latter the report said that he *'merits being awarded posthumously the Hero of the Soviet Union title'*. The report also contained a solicitation for a monument to be erected in honour of Bakhchivandzhi. The report was signed by Viktor F. Bolkhovitinov, Chief Designer and director of plant No.293.

On 17th October 1942 Grigoriy Ya. Bakhchivandzhi was awarded the Order of Lenin for the testing of the world's first combat fighter powered by a liquid-fuel rocket motor; as for the title of Hero of the Soviet Union, it was conferred on Bakhchivandzhi posthumously with a 40-year delay – on 28th April 1973. Additionally, after the war a minor railway station of the Moscow Railroad was named Bakhchivandzhi.

In 1943 a new wind tunnel, the T-106, was commissioned at TsAGI; it was intended for high-speed tests. This wind tunnel immediately came to be widely used for the testing of aircraft models and elements of full-size aircraft at high subsonic speeds. Among others, a model of the BI aircraft was also tested with a view to elucidating the causes of the crash. The tests results showed clearly that the BI had crashed owing to the designers' failure to take account of some peculiarities of the airflow around unswept wings and tail surfaces at transonic speeds. These peculiarities made the aircraft prone to entering a dive from which the pilot could not recover.

After Bakhchivandzhi's death the 30 unfinished BI-VS aircraft were destroyed, but the work on this programme continued for a while. To study the possibility of increasing the endurance of the BI rocket-propelled interceptor, which was a mere two minutes, a modification of this aircraft with wingtip-mounted ramjet engines was considered in 1943-44. The sixth example of the aircraft (BI No.6 or BI-6) serialled '6 White' was fitted with ramjets installed in wingtip pods; the rocket motor was removed in so doing. In 1944 the aircraft was tested in the TsAGI T-101 wind tunnel permitting the testing of full-size aircraft, but that was the final chord marking the termination of this programme. An attempt was made, though, to make the cockpit of one of the BI airframes hermetically sealed by gluing rubber strips to all the joints.

In January 1945, upon returning to Moscow, test pilot Boris N. Koodrin performed two flights in a ski-equipped BI interceptor powered by an Isayev RD-1 rocket motor; the latter was a development of the D-1A-1100 motor. In one of these flights at an all-up weight of 1,800 kg (3,960 lb) and a speed of 587 km/h (365 mph) the fighter's rate of climb near the ground reached 87 m/sec (17,127 ft/min). During the flights of the BI No.7 (BI-7), which differed from the other examples in having fairings at the wing/fuselage junction and fairings for the arc starter on the motor cowlings, vibration and buffeting of the tail unit arose. To investigate the causes of these phenomena, the fifth and sixth examples – the BI No.5 ('5 White') and BI No.6 – were modified in a fashion similar to the configuration of the BI No.7. In March-April 1945 they were flight-tested in glider mode (without igniting the rocket motors); a North American B-25J Mitchell bomber operated by LII acted as the towplane. The BI No.5 was fitted with skis and the BI No.6 had a normal wheel undercarriage. No buffeting or vibration was discovered in these flight. In all probability, these flights were the last flights of the BI, because shortly afterwards all further work on this programme was terminated. In all, apart from the unfinished service test batch machines, nine prototypes of the BI rocket-propelled interceptor were built for various kinds of tests.

The bosses of the Soviet aircraft industry were dissatisfied first of all with the exceedingly small endurance of the BI, which was not compensated by its 50% higher speed as compared to piston-engined fighters. However, the experience accumulated during the work on this programme later proved useful to many of the employees of OKB-293. Aleksandr Ya. Bereznyak, Aleksey M. Isayev and Viktor F. Bolkhovitinov, as well as Leonid S. Dooshkin, the engine designer, participated in the development of other projects of Soviet rocket-propelled interceptors after the war.

The BI Interceptor in Detail

Type: Single-seat short-range interceptor. The airframe was of all-wooden construction.

Fuselage: Monocoque structure of elliptical cross-section with frames, stringers and a plywood skin covered with a layer of linen fabric. The forward extremity of the fuselage was a parabolic fairing housing the armament bay with a detachable access cover. Aft of this was the cockpit enclosed by a canopy blended into the fuselage contours; it comprised a fixed windshield and an aft-sliding rear section. The lower forward fuselage housed two air bottles and two kerosene tanks; more air bottles and the nitric acid tanks were located aft of the cockpit. The air bottles weighed 22.4 kg (49.38 lb), while the kerosene tanks and the nitric acid tanks weighed 31.2 kg (68.78 lb) and about 80 kg (176 lb) respectively; the assorted other equipment housed in the fuselage weighed about 20 kg (44 lb). The pilot was protected by a forward armour plate and an armoured seat back, both of which were 5.5 mm (0$\frac{7}{32}$ in) thick.

Wings: Cantilever low-wing monoplane with wings of trapezoidal planform; no sweepback, taper 2.5. The wings were a one-piece assembly of bonded ten-spar construction; the spars were joined by bonded plates running along the entire span above and below. The wings utilised the TsAGI V-1-10 airfoil with a thickness/chord ratio of 12% throughout.

The wings were fitted with hydropneumatically actuated Schrenck flaps of duralumin construction; the flaps were suspended on

Specifications of the RD-1A-1100 Rocket Motor

Thrust at sea level, kgp (lbst)	1,100 (2,425)
Specific thrust, kgp/sec (lbst/sec)	204 (450)
Combustion chamber volume, litres (Imp gal)	19 (4.18)
Fuel consumption, kg/sec (lb/sec)	1.05 (2.31)
Oxidiser consumption, kg/sec (lb/sec)	4.35 (9.58)
Fuel/oxidiser proportion	1:4.14
Combustion chamber pressure, kg/cm^2 (psi)	16 (221)
Weight, kg (lb)	48 (105.8)
Sustained operation time, seconds:	
minimum thrust mode	200
full power mode	70
Service life, minutes	18-20

piano hinges and deployed up to 50° for landing. Ailerons with a remarkably short span (one-third of the wing half-span) were located outboard of the flaps; they had a duralumin frame and a fabric skin.

Tail Unit: Conventional unswept tail surfaces of trapezoidal planform; the fin had a rounded tip. The *vertical tail* was augmented with a small ventral fin mounting the tailwheel and by small circular endplates mounted at the tips of the horizontal tail. The stabilisers had zero dihedral and were strut-braced from above and wire-braced from below. The fin and stabiliser were skinned with 2-mm (0⁵⁄₆₄ in) plywood; the fabric-covered rudder and elevators had duralumin frames.

Landing Gear: Tailwheel landing gear with single wheel on each unit. The main units with 500 x 150 mm (19.68 x 5.90 in) wheels retracted inwards pneumatically into the wings. The 90 x 42 mm (3.54 x 1.65 in) tailwheel was non-retractable and non-castoring. Skis could be fitted in winter; the 1,440 x 300 m (56.29 x 11.81 in) main skis were retractable and incorporated sprung shock absorbers.

Powerplant: One RDA-1-1100 (RD-1-A-1100) liquid-fuel rocket motor housed in the rear fuselage. The propellants (kerosene and nitric acid) were stored in welded tanks made of Cromansil steel.

The rocket motor consisted of three principal modules:

- a dome-type combustion chamber head with main fuel injectors (arranged in concentric circles) and a start-up unit with start-up fuel injectors and igniters;
- a combustion chamber cooled by the oxidiser flow;
- a nozzle section cooled by the fuel flow.

The scarcity of stainless steel led the designers of the engine to use grade S-54 high-carbon steel, the engine parts made of it being chrome-plated inside and out. Metal and aluminium rings were used as the gaskets preventing seepage of hot gases between the modules. Grommets are fitted around the combustion chamber head and the nozzle's diffuser to compensate for the engine's thermal expansion. The main specifications of the rocket motor are given in the table on page 27.

Armament: Two 20-mm (.78 calibre) Shpital'nyy/Vladimirov ShVAK cannons in the fuselage nose, with 45 rounds per gun. The cannons were controlled electrically and cocked pneumatically. BI-VS pre-production aircraft intended for service trials were to carry a cassette (dispenser) for bomblets with a total weight of 38.4 kg (84.6 lb).

Specifications of the BI Interceptor

Length, tail up	6.935 m (22 ft 9 in)*
Height on ground	2.175 m (7 ft 1⅝ in)
Wing span	6.615 m (21 ft 8⁷⁄₁₆ in)†
Wing span, BI No.6:	
measured at the ramjets' axes	7.352 m (24 ft 3²¹⁄₆₄ in)
less ramjets	6.508 m (21 ft 4⁷⁄₃₂ in)
Wing area, m² (sq ft)	7.04 (75.69)
Stabiliser span:	
Including endplate fins	1.95 m (6 ft 4⁴⁹⁄₆₄ in)
less endplate fins	1.843 m (6 ft 0³⁵⁄₆₄ in)
Diameter of endplate fins	0.5 m (1 ft 7¹¹⁄₁₆ in)
BI No.6 ramjet pods:	
length	1.77 m (5 ft 9⁴³⁄₆₄ in)
diameter	0.65 m (2 ft 1¹⁹⁄₃₂ in)
Landing gear track	1,814 m (5 ft 11¹³⁄₃₂ in)
Landing gear wheelbase	3.48 m (11 ft 5 in)
Empty weight, kg (lb):	
first prototype	790 (1,740)
pre-production	805 (1,774)
Airframe weight, kg (lb):	462 (1,018)
including	
fuselage	182 (401)
tail unit	30 (66)
landing gear	60 (132)
control system	16 (35)
rocket motor	48 (105)
Armament weight, kg (lb)	76 (167)
Bulletproof windshield weight, kg (lb)	6 (13)
Full load, kg (lb):	860 (1,895)
including	
pilot	90 (198)
nitric acid	570 (1,260)
kerosene	135 (297)
cannon ammunition	19.6 (43.2)
bombs	38.4 (84.6)
Take-off weight, kg (lb):	
first prototype	1,650 (3,640)
seventh prototype	1,800 (3,970)
pre-production	1,683 (3,710)
Top speed, km/h (mph):	
at sea level (design figure)	800 (496)
at high altitude (design figure)	1,020 (633)
as actually attained	675 (419)
Landing speed, km/h (mph)	143 (88)
Endurance, minutes:	
design figure	15
as actually attained	about 7
Maximum rate of climb, m/sec (ft/min)	82 (16, 140)
Acceleration time to 800 km/h (496 mph), seconds	20
Climb time to 5,000 m (16,400 ft), seconds (design figure)	30
Service ceiling, m (ft) (design figure)	10,000 (32,810)
Maximum altitude attained, m (ft)	about 4,000 (13,120)
Destructive G load	9
Destructive G load at 1,100 kg (2,425 lb) with partial fuel load	13.5

* Some documents say 6.4 m (20 ft 11⁶³⁄₆₄ in)

† 6.48 m (21 ft 3⅛ in) according to drawing

Chapter 2

The '302' and '302P'

In mid-1940 the Rocket Propulsion Research Institute (RNII), which was then headed by Chief Engineer A. G. Kostikov, started design work on one of the first jet aircraft in the USSR. Andrey Grigor'yevich Kostikov had earned a controversial reputation in his capacity as the leader of RNII; yet he was a very competent engineer. He was among the first to suggest a fully feasible way of addressing the main deficiency of the BI rocket-propelled interceptor created by V. F. Bolkhovitinov's OKB – its extremely short endurance. The problem was to be dealt with by supplementing the liquid-fuel rocket motor with ramjet cruise engines. The rocket motor would allow the fighter to reach the necessary speed and operating altitude quickly, while the ramjets were intended to maintain these characteristics at a level superior to the performance of the best piston-engined fighters. This idea seemed to be an enticing one.

The single-seat interceptor under development at RNII bore the provisional designation '302'. The project envisaged the use of a composite powerplant consisting of two cruise ramjets and a liquid-fuel rocket motor intended for take-off (it was also termed a booster engine). Actually, this was the world's first project of a fighter featuring a composite jet propulsion powerplant. A team led by engineer M. K. Tikhonravov under the overall guidance of A. G. Kostikov undertook the actual design work.

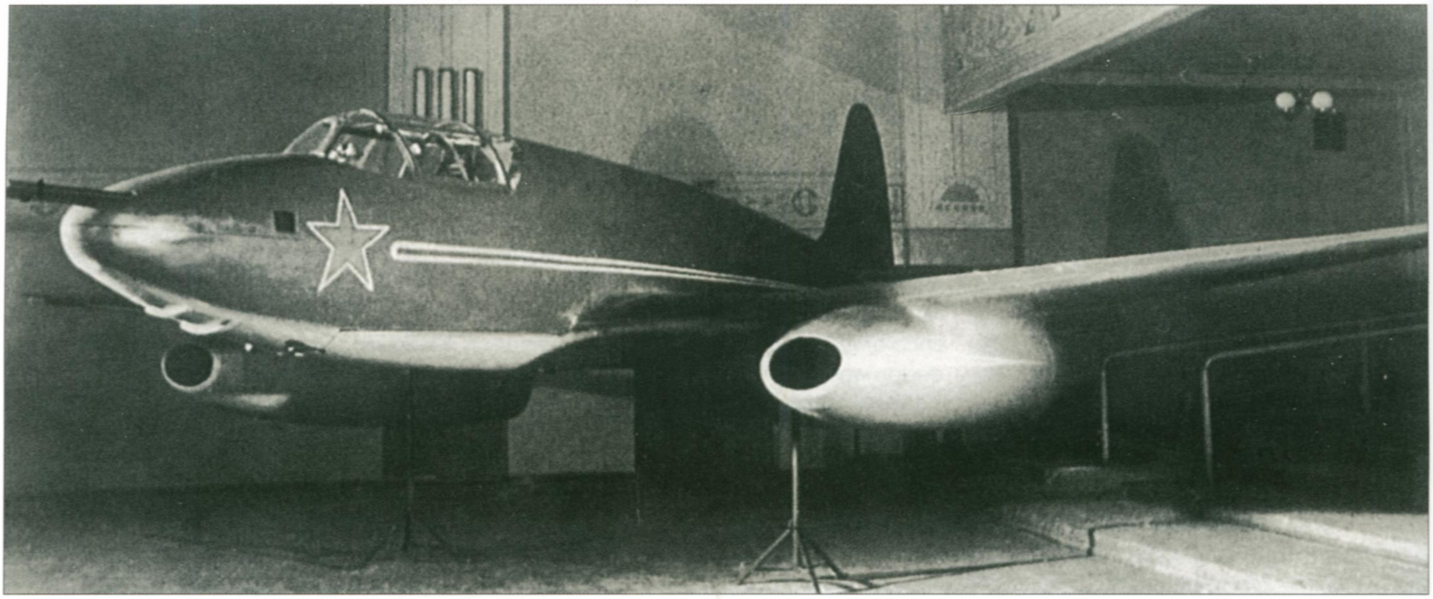
Development of the RD-1400 liquid-fuel rocket booster engine was likewise undertaken at RNII by a team led by Leonid S. Dooshkin. It had a nominal thrust rating of 1,100 kgp (2,425 lbst) and a maximum thrust of 1,400 kgp (3,090 lbst). Tractor-grade kerosene was quite suitable as fuel for this engine, with nitric acid as the oxidiser. The fuel components were stored in fuselage tanks equipped with pumps for feeding the propellants to the combustion chamber. In an emergency the fuel components could be jettisoned in flight through special valves and drain pipes. The rocket motor itself was mounted on a tubular truss in the aft fuselage.

According to the designers' concept, the cruise ramjets were to be ignited after take-off when the aircraft reached an altitude of some 50 m (160 ft) and a speed of at least 260 km/h (162 mph). The ramjets were to run on aviation gasoline stored in wing tanks. Since the thrust developed by the ramjets depended to a considerable degree on the flight speed and altitude, its working value in calculations was usually replaced by a more stable parameter – the specific impulse which, in this case, equalled 699-800 sec for each engine. On the '302' aircraft the ramjets were located at a distance of 1.75 m (5 ft 9 in) from the centreline. A team led by V. S. Zooyev designed the ramjets at RNII, while G. N. Abramovich was responsible for the scientific guidance of the work on the gas flow duct and of the associated experiments; for this purpose he established a special subdivision in the TsAGI section in his command.

Since the ramjets and the rocket motor were quite 'thirsty', the active section of the '302' interceptor's flight path was limited to a few minutes, in the course of which the aircraft was to climb to altitude and to attack the enemy, whereupon it broke off combat and made a gliding descent to base. Bearing this in mind, the designers focused their attention not so much on high-speed aerodynamics as on reducing the machine's drag. The airframe of the '302' aircraft had an unprecedentedly high lift/drag ratio for an aircraft of its size; this was achieved by carefully streamlining the aircraft's contours.

The interceptor was of wooden construction. The fuselage was an oval-section semi-monocoque structure built up by gluing stripes of birchwood veneer and reinforced by wooden longerons. Its forward section provided accommodation for two 20-mm (.78 calibre) Shpital'nyy/Vladimirov ShVAK cannons enclosed by a duralumin cowling. To improve forward and downward visibility, the cross-section of the forward fuselage was

A session of RNII's Scientific Council during the development of the '302' interceptor in 1940 or 1941. Left to right: A. E. Schwarz, M. K. Tikhonravov, S. A. Pivovarov, V. A. Artem'yev, V. A. Shtokolov, L. S. Dooshkin, V. N. Galkovskiy, A. G. Kostikov, I. S. Rabinovich and Yu. A. Pobedonostsev.



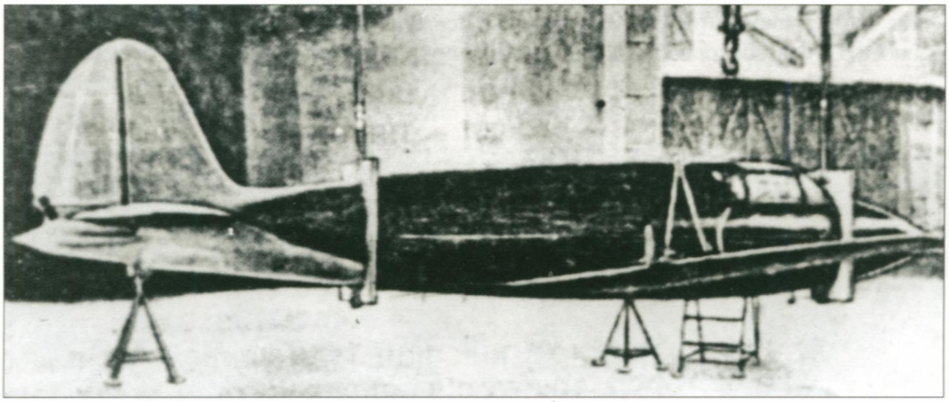
Above: A full-scale mock-up of the '302' interceptor with the landing gear retracted. Note the elliptical air intakes of the cruise ramjets and the protruding cannon barrels.

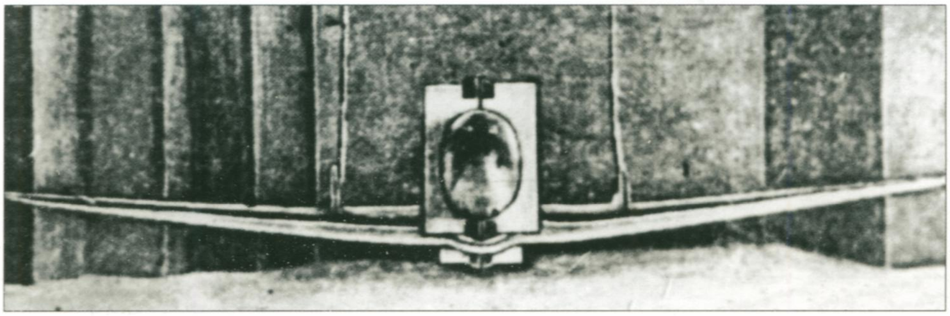
reduced to the barest minimum. This necessitated locating the ammunition boxes in tandem; hence the cannons were mounted in a staggered arrangement, the starboard cannon being placed further forward. Two more ShVAK cannons were located under the cockpit in order to increase the weight of fire – a characteristic of utmost importance for a fighter in the conditions of short-duration combat. The total ammunition supply was 400 rounds. The firepower was enhanced by RS-82 or RS-132 rocket projectiles mounted on extendable launch rails under the wings. For attacking ground targets, the aircraft could carry two 125-kg (276-lb) bombs. The pilot was protected from enemy fire by a bulletproof windscreen in the fixed windshield and by an armour plate located under the instrument panel. To provide access to the cockpit, the movable part of the canopy hinged open to starboard.

The wings were of wooden construction and had pronounced taper. The airfoil section varied along the span; the wing centre section utilised the RAF-34 airfoil with a thickness/chord ratio of 15%, while the NACA-230 airfoils used in the outer wing panels changed their thickness/chord ratio from 15% at the root to 8% at the tip. To ensure adequate lateral stability, the wing centre section had 2°37' dihedral, the outer wings having 6° dihedral. The leading-edge sweepback on the outer wings was 8°, increasing to 8°35' on the centre section. 64% of the wing span was occupied by trailing-edge flaps. The fin was built integrally with the fuselage, and the stabilisers were attached to the fuselage above the section housing the rocket motor. The rudder, elevators and ailerons had duralumin frames with fabric covering. The rudder was controlled by rigid linkages, while the ailerons and elevators utilised cable linkages. The tailwheel undercarriage was hydraulically retractable.

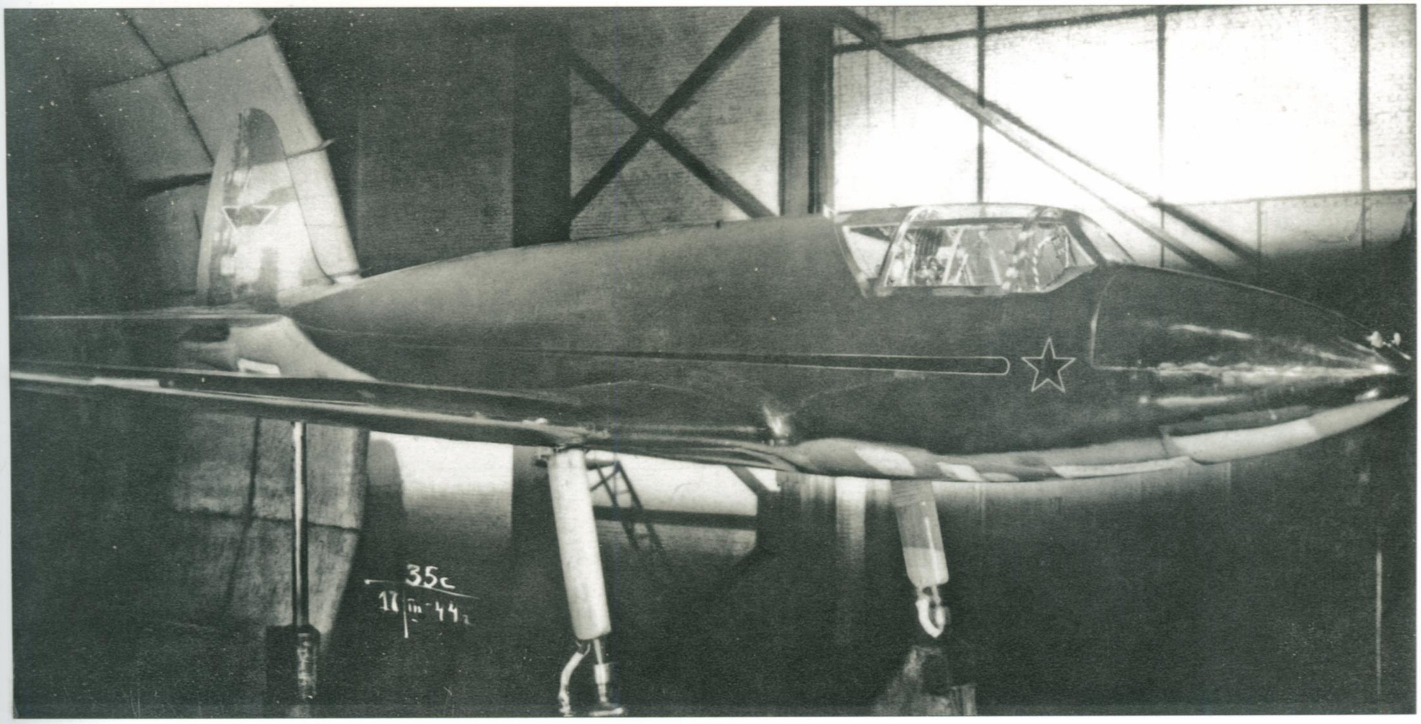
On 5th February 1941 the project of the '302' fighter in the configuration described above was submitted to the technical council of RNII and endorsed for further elaboration as a part of the institute's plan for the nearest future. However, on the second day after the outbreak of the war with Germany (the Great Patriotic War) the preparation of the fighter's detail drawings was halted because the institute and its experimental production facility switched to the manufacture of the BM-13 multiple-launcher rocket system (later popularly known as the *Katyusha*); the institute's staff and Chief Designer Andrey G. Kostikov himself had their hands full with this work.

In October 1941 RNII was evacuated to Sverdlovsk where the work on the aircraft was continued by enthusiasts during their spare time – that is to say, mainly at night. In January 1942 the project was submitted initially to a commission of the Military Air Academy named after Nikolay Ye. Zhukovskiy and subsequently sent to TsAGI. On 15th July that year the State Defence Committee issued resolution No.2046 transforming RNII into NII-3





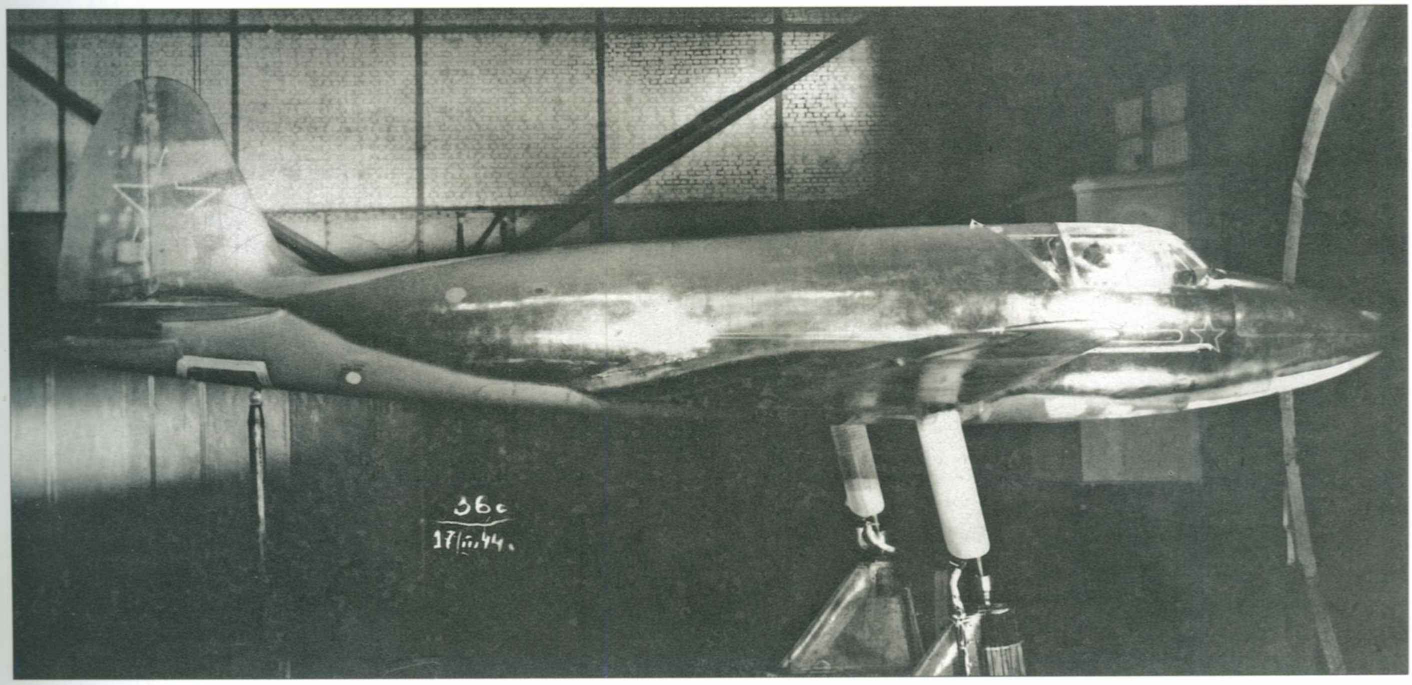
Top and above: The short-wing version of the '302' interceptor lacking ramjet engines (known as the '302P') being weighed; the yoke-like devices fitted around the fuselage served for lifting it.



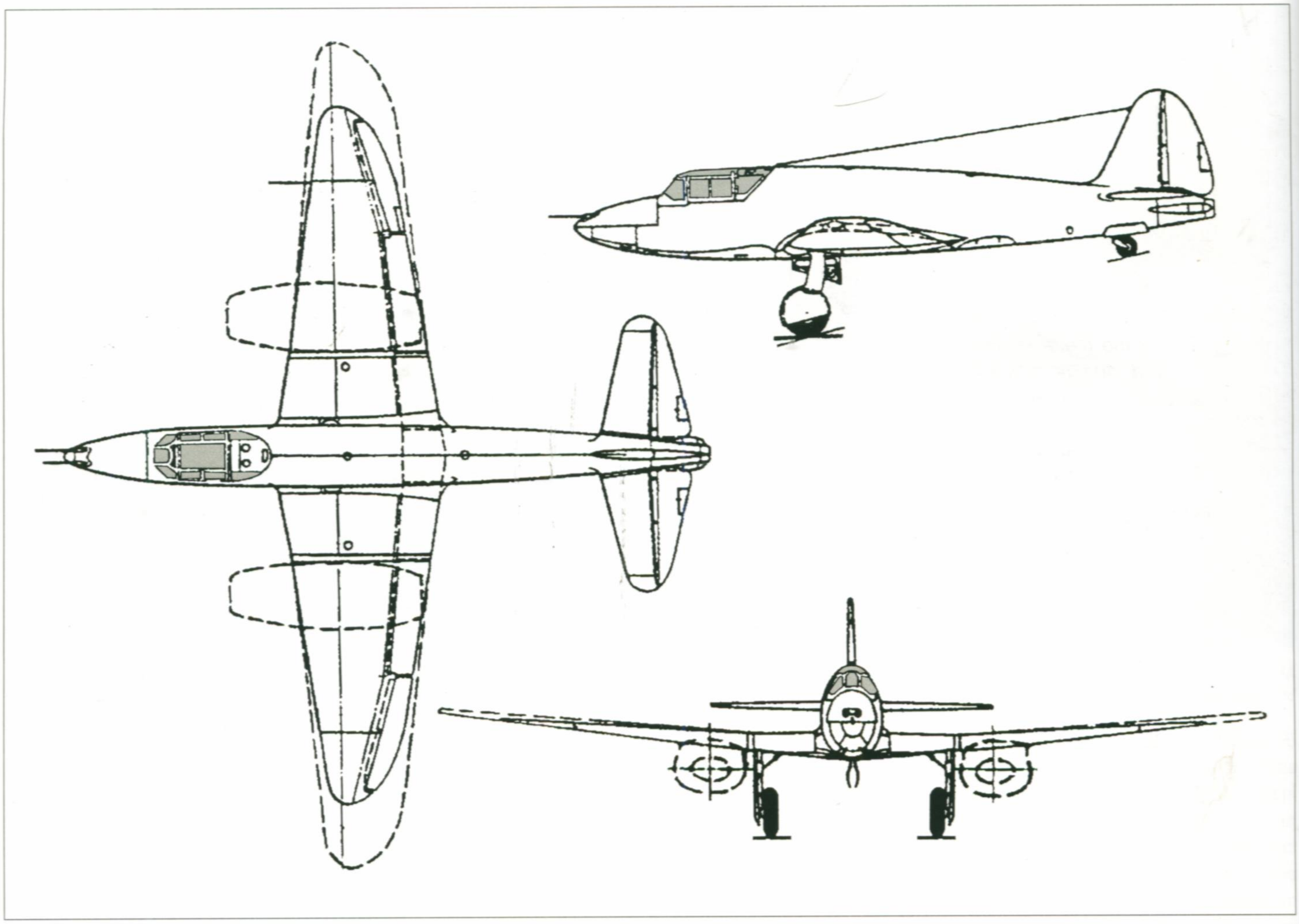
Above: The as-yet engineless '302P' undergoing wind tunnel tests at TsAGI; the main gear struts are fixed to act as attachment points, while the tail is supported by a special strut.

(Research Institute No.3) for Rocket Propulsion Technology; Kostikov was appointed the institute's Chief Designer and director of the prototype construction plant No.55. Albeit the institute was formally part of the system of enterprises controlled by the People's Commissariat of Defence Industry, in practice it was subordinated directly to the Council of People's Commissars (SNK – *Sovet narodnykh komissarov*), that is, the Government.

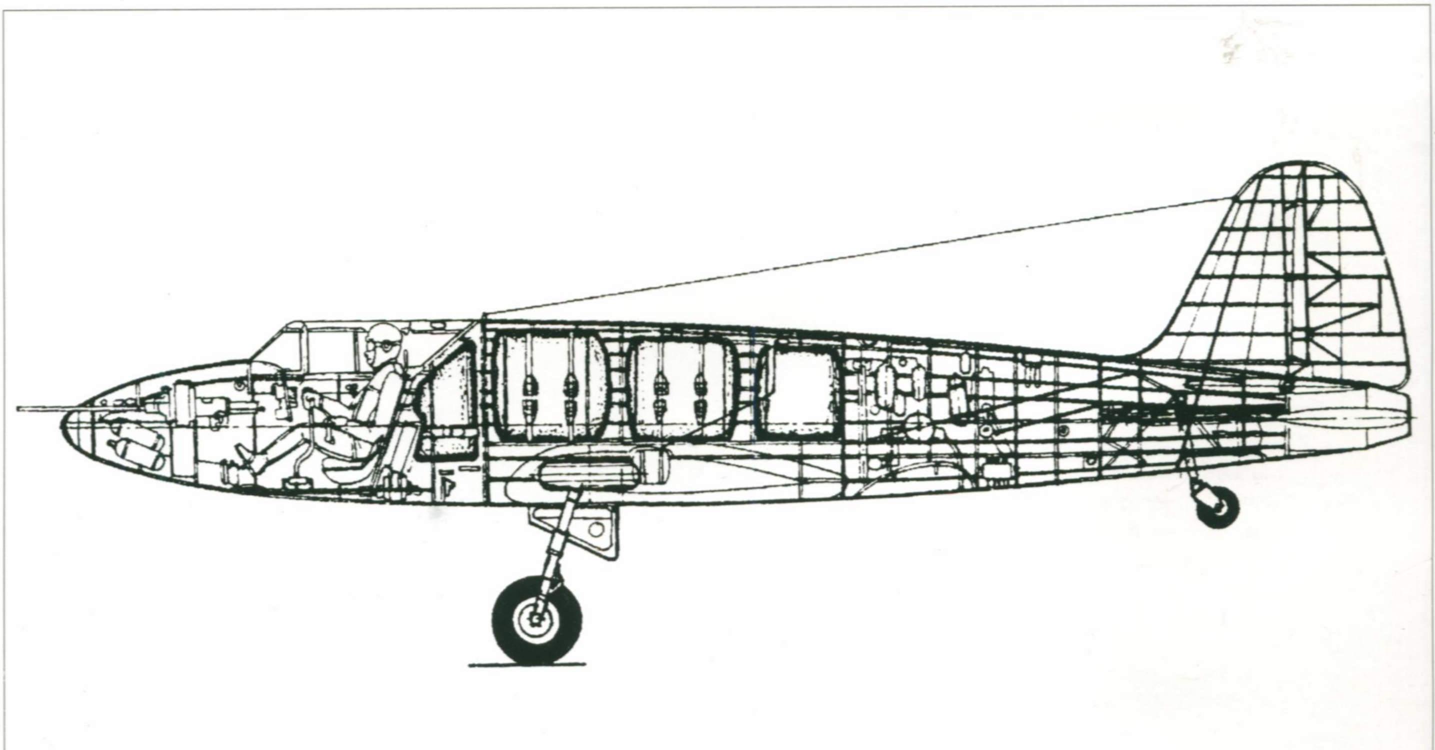
On 17th-18th July 1942 an authoritative NKAP commission including A. K. Martynov, S. A. Khristianovich, A. V. Chesalov, S. N. Shishkin, V. I. Polikovskiy and several other members endorsed the project of the '302' fighter; this gave Kostikov a pretext to inform the persons in the top echelon of power about the project. The leader of the institute managed to obtain an audience with Kliment Ye. Voroshilov, the then People's Commissar of Defence, and the result was felt immediately. On the same day Stalin personally gave his approval to the ADP of the '302' interceptor. However, somewhat earlier, on 26th July 1942, the State Defence Committee in its resolution No.2150 once again tasked NII-3 with developing yet another version of the rocket-propelled interceptor. The task was to be fulfilled within a very stringent time limit – just one year. At about the same time, in July, the institute prepared two reports on the aircraft. They contained a summary of weights, a short technical description and aerodynamic calculations. The reports cited a speed of 800 km/h (497 mph) and an all-up weight of 3,360 kg (7,409 lb) for the interceptor; the



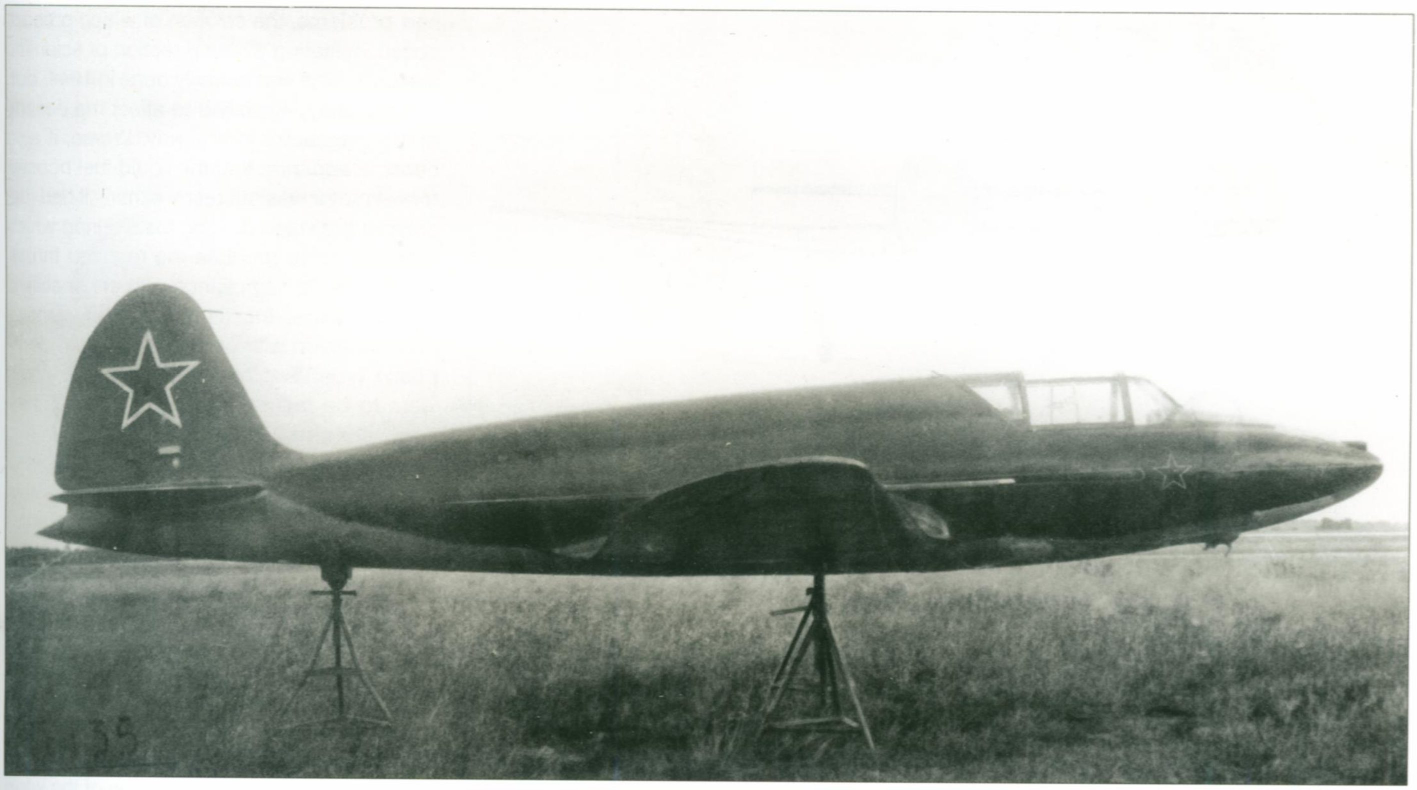
Another view of the '302P' in the wind tunnel, showing the clean lines of the aircraft.



Above: A three-view of the '302P'. The hatched lines in the front and upper views illustrate the longer-span wings and cruise ramjets of the original '302'. Note the staggered nose cannons.



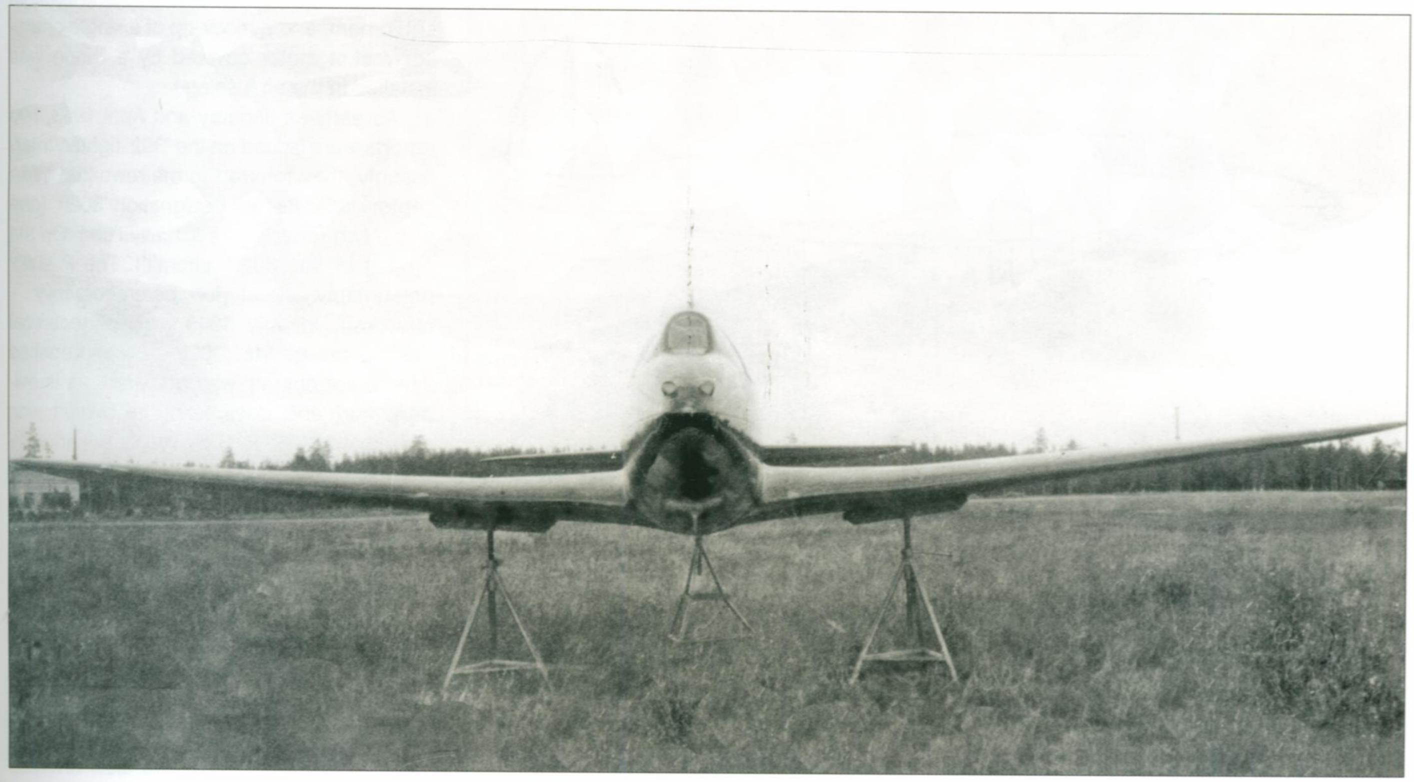
A cutaway drawing of the '302', showing the fuel and oxidiser tanks for the rocket motor, which is located in the tailcone. Note the ventral cover for access to the fuel system components.



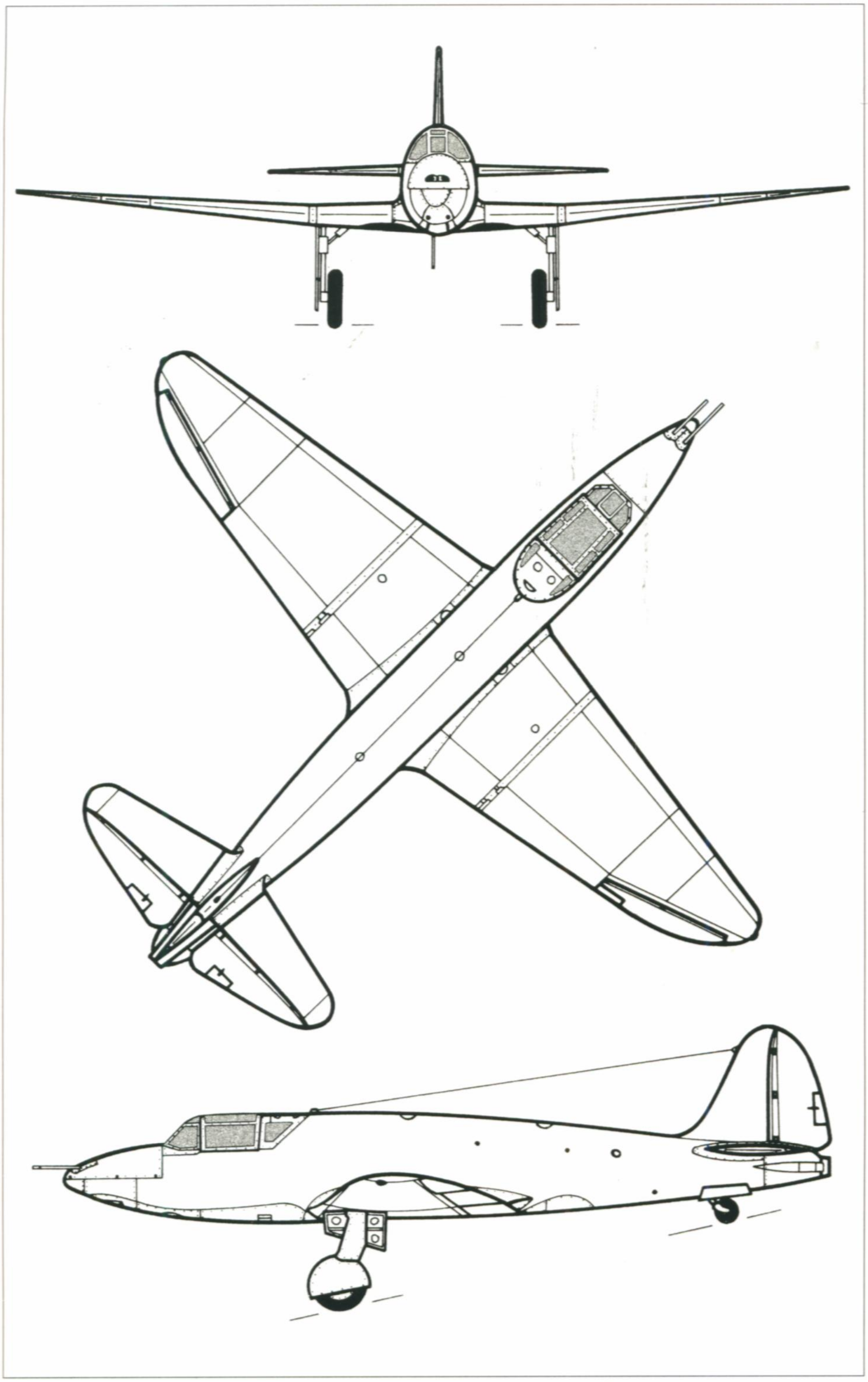
Above: The '302P' trestled in the open for alignment checks. Note the strong wing dihedral and the fairing closing the nozzle of the still-unavailable rocket motor. The excrescence on the underside of the nose is the towing hook.

aircraft was to be powered by an RD-1100 rocket motor delivering a normal thrust of 1,100 kgp (2,425 lbst) and a maximum thrust of 1,400 kgp (3,090 lbst).

In early 1943 a new OKB (design bureau) was set up within NII-3 for Rocket Propulsion Technology. It was OKB-55 – to be precise, the design bureau of plant No.55 which acted as the institute's experimental production facility. OKB-55 was headed by Matus R. Bisnovat who had been transferred to that plant; his deputy was A. A. Andreyev. Both men had substantial experience of aircraft design – one of them had worked for a long time in a TsAGI team led by Nikolay N. Polikarpov, the other had worked in the TsKB (Central Design Bureau, an NKVD outfit for convicted engineering staff) and in the OKB led by Sergey A. Kocherigin. V. D. Yarovitskiy was invited to take on the structural strength calculations, while M. K. Tikhonravov was in charge of



A front view of the trestled '302P', showing how the dihedral changes along the span. Note the faired-over apertures for the forward cannons.



This three-view shows the interceptor in the '302P' short-span, rocket-only powered configuration. Note the detachable cowling under the cockpit for access to the lower pair of cannons.

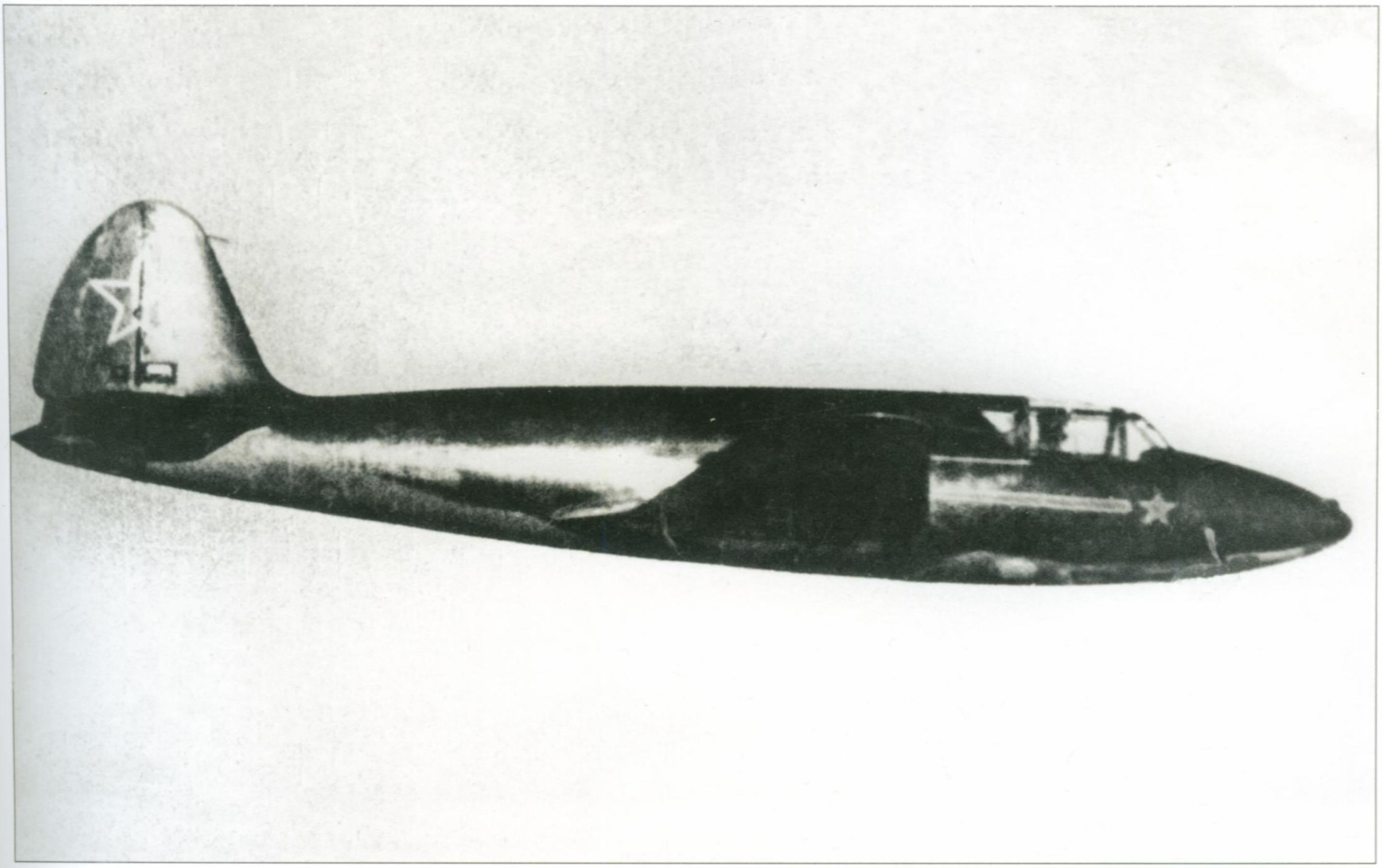
aerodynamic calculations. In parallel with the preparation of detail drawings a wooden full-scale mock-up was being constructed.

In mid-January the mock-up of the '302' interceptor with a composite powerplant (one liquid-fuel rocket motor and two ramjets) was submitted for inspection to NKAP leaders. Manufacture of two prototypes was initiated. Yet, while the airframe did not pose any special problems, the situation with the powerplant caused serious concern. By the spring of 1943 it became apparent that the ramjets, then under development by V. S. Zooyev, would not be available on schedule. They had only reached the stage of half-scale models and had not passed a complete test programme. The work on the ramjets called for additional serious research, both theoretical and experimental. The internal aerodynamics of a ramjet posed a number of completely new problems, the solution of which presupposed instituting a new direction of scientific research. This was actually done in 1944, but, unfortunately, this failed to affect the destiny of the interceptor in any way. Worse, it also became apparent that the liquid-fuel booster rocket motor was not ready either – it had just entered the stage of firing tests during which it had failed to produce the required thrust.

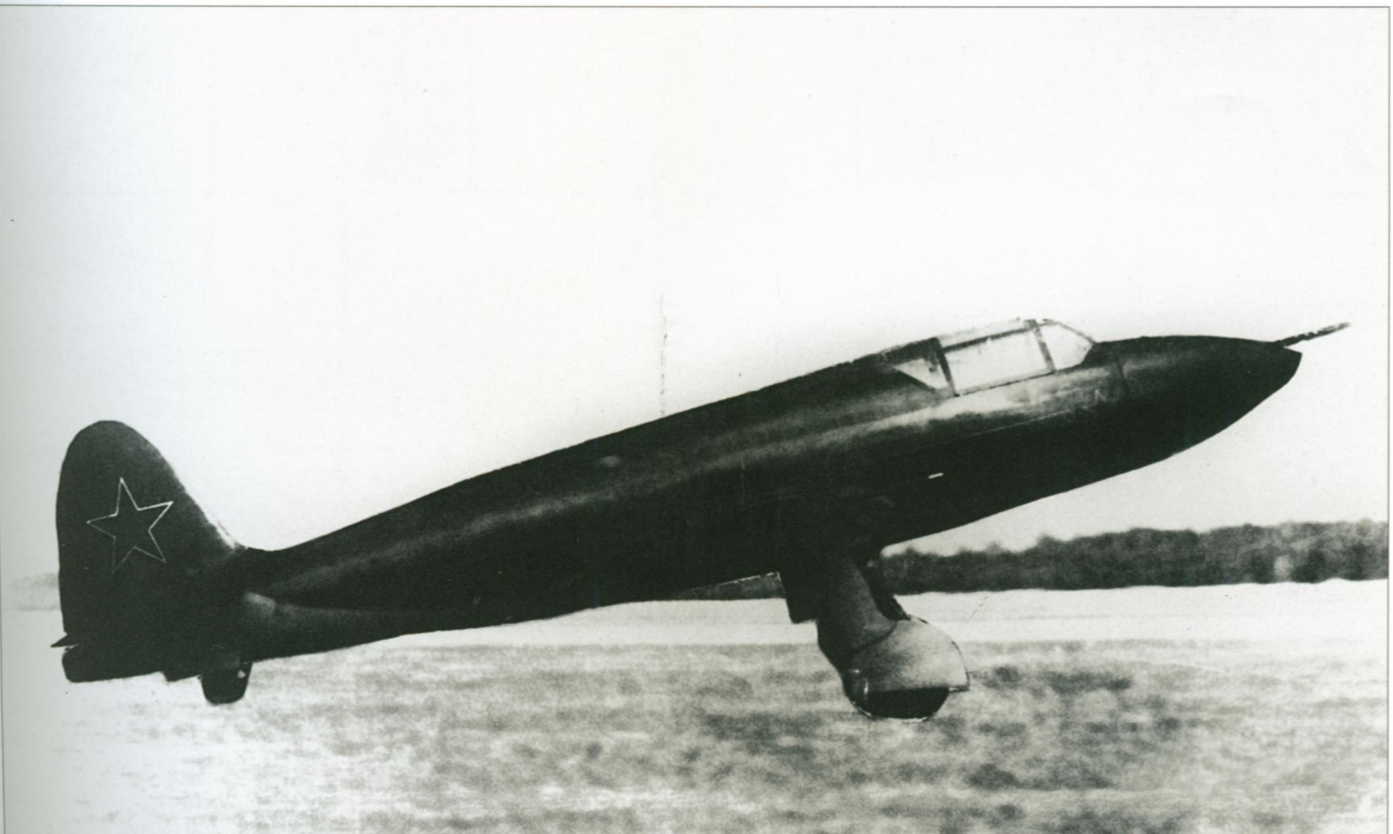
To ensure compliance with the specified characteristics, the designers even considered a version with cruise engines of a composite type. Two 'pseudo-turbojet' engines were to be mounted under the wings, their axial compressors being driven by two Shvetsov M-11 five-cylinder radial engines installed in the fuselage! However, this scheme offered more problems than solutions to them, and eventually the team stopped experimenting with the powerplant. It was decided to concentrate on the fighter version powered by one RD-1400 liquid-fuel rocket motor which, by that time, had been redesignated D-1-A. It had the benefit of having flown in one of the BI interceptor prototypes. Now that the ramjets had to be abandoned, this led to a revision of the wing structure – the wing span was reduced from 11.1 m (36 ft 5 in) to 9.55 m (31 ft 4 in). Furthermore, the tanks housed in the wing centre section and holding 180 litres (39.6 Imp gal) each now came to be used for the rocket motor propellants. The total weight of kerosene carried by the aircraft rose to 505 kg (1,113 lb), the weight of the oxidiser (nitric acid) reaching 1,230 kg (2,710 lb). The aircraft was stripped of armament and some items of equipment, and a mock-up of a single-chamber rocket motor covered by a fairing was installed in the aft fuselage.

As early as January and April 1943, two reports were issued on the '302' fighter. Interestingly, they referred to the reworked interceptor under its new designation '302P' (one of the two reports was actually titled 'On the project of the '302P' aircraft'). The P suffix presumably stood for *perera**bot**annyy* – reworked. In July 1943 a 'Brief technical description of the '302P' rocket-propelled interceptor aircraft' was prepared. As is evident from the document, the aircraft was developed by M. R. Bisnovat, A. A. Andreyev and Mikhailov. NII-3 chief A. G. Kostikov endorsed the document on 15th September.

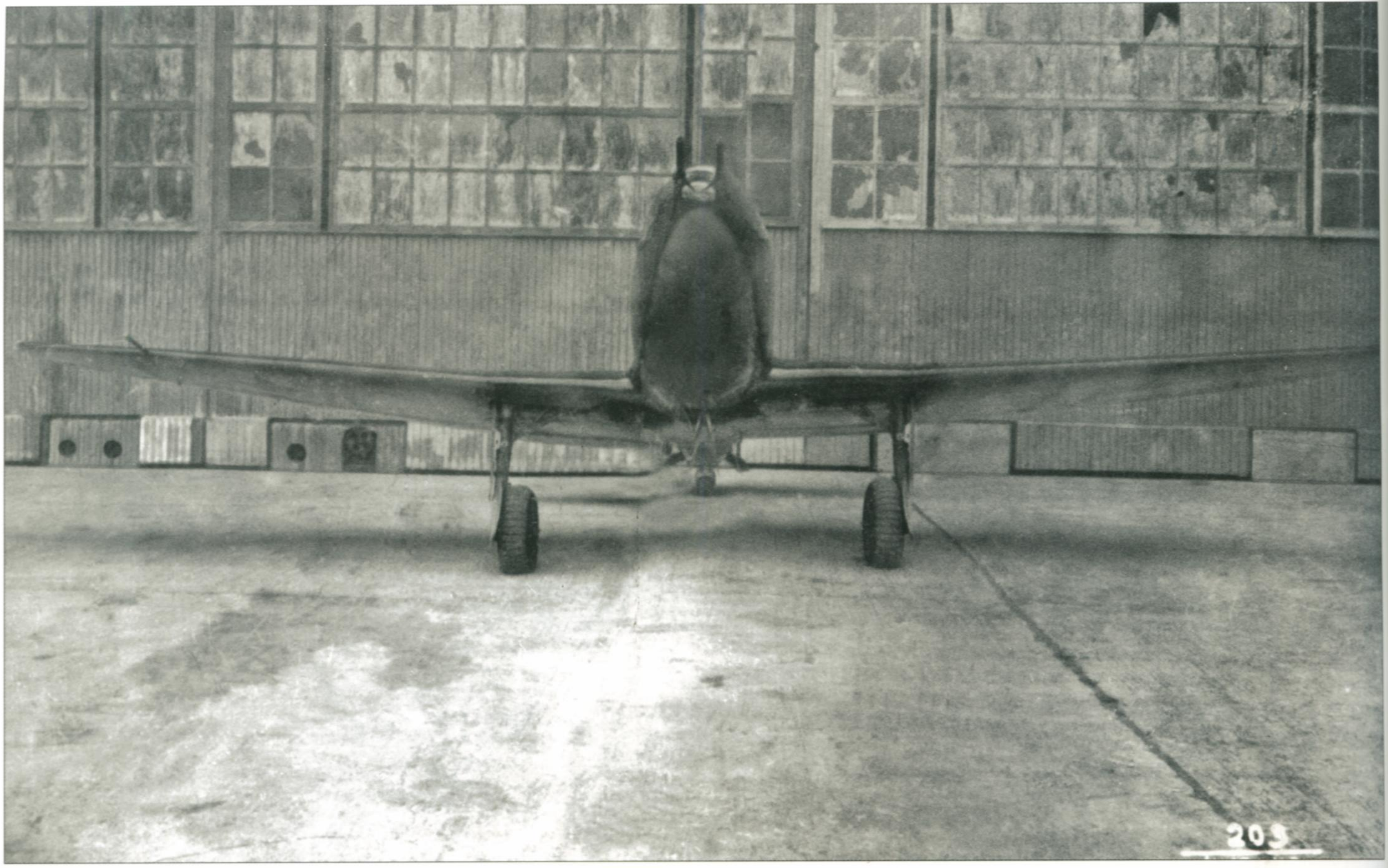
It was in this reworked configuration that the '302P' interceptor was submitted for flight tests to the Flight Research Institute (LII) in late August 1943. V. N. Yelagin was appointed project engineer in charge of the tests. Several dozen flights were performed in glider configuration, with no rocket motor fitted; the aircraft's behaviour in this configuration was thoroughly studied. The tests revealed that the stability left something to be desired.



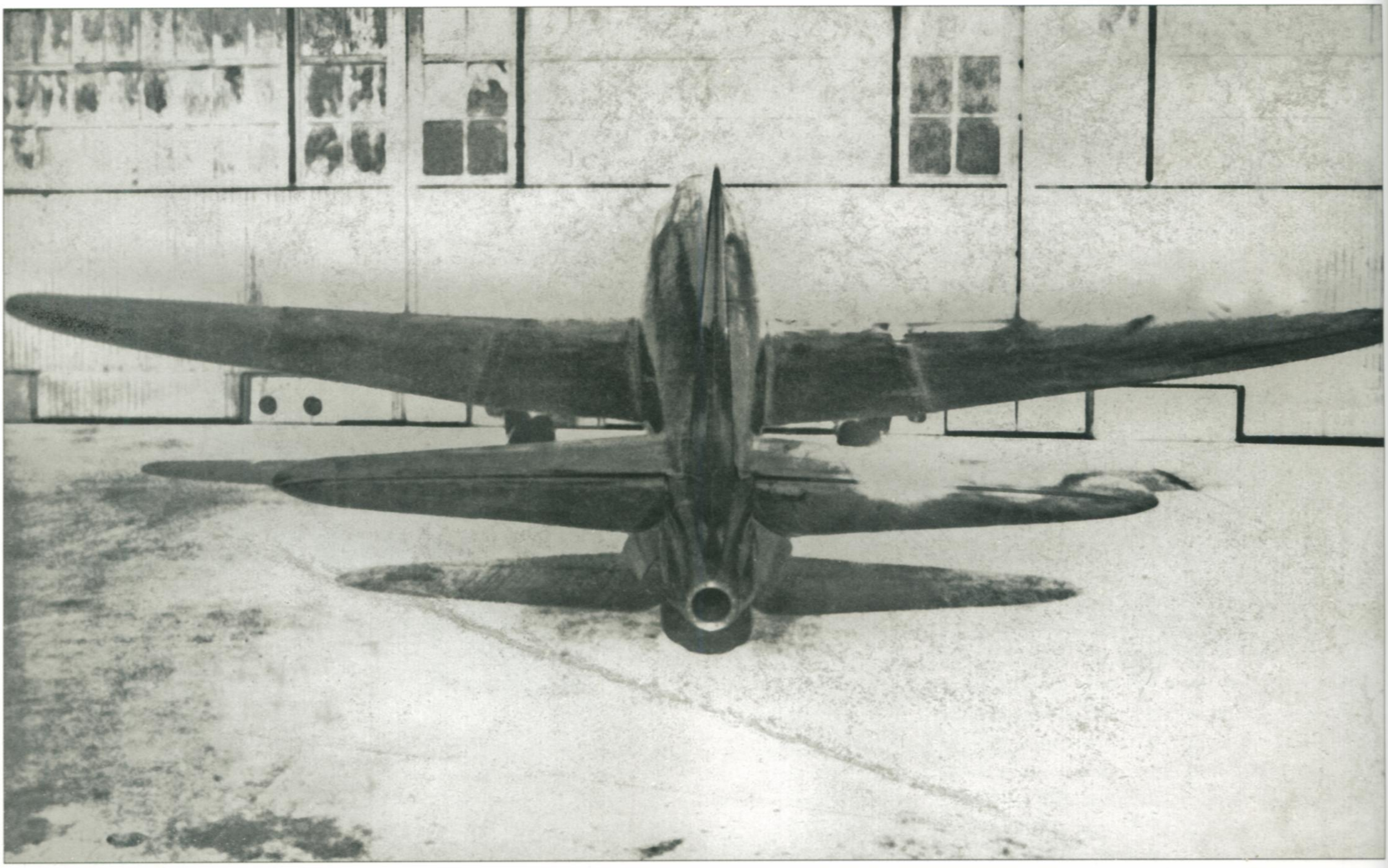
Above: An air-to-air shot of the engineless '302P' taken during initial gliding trials.



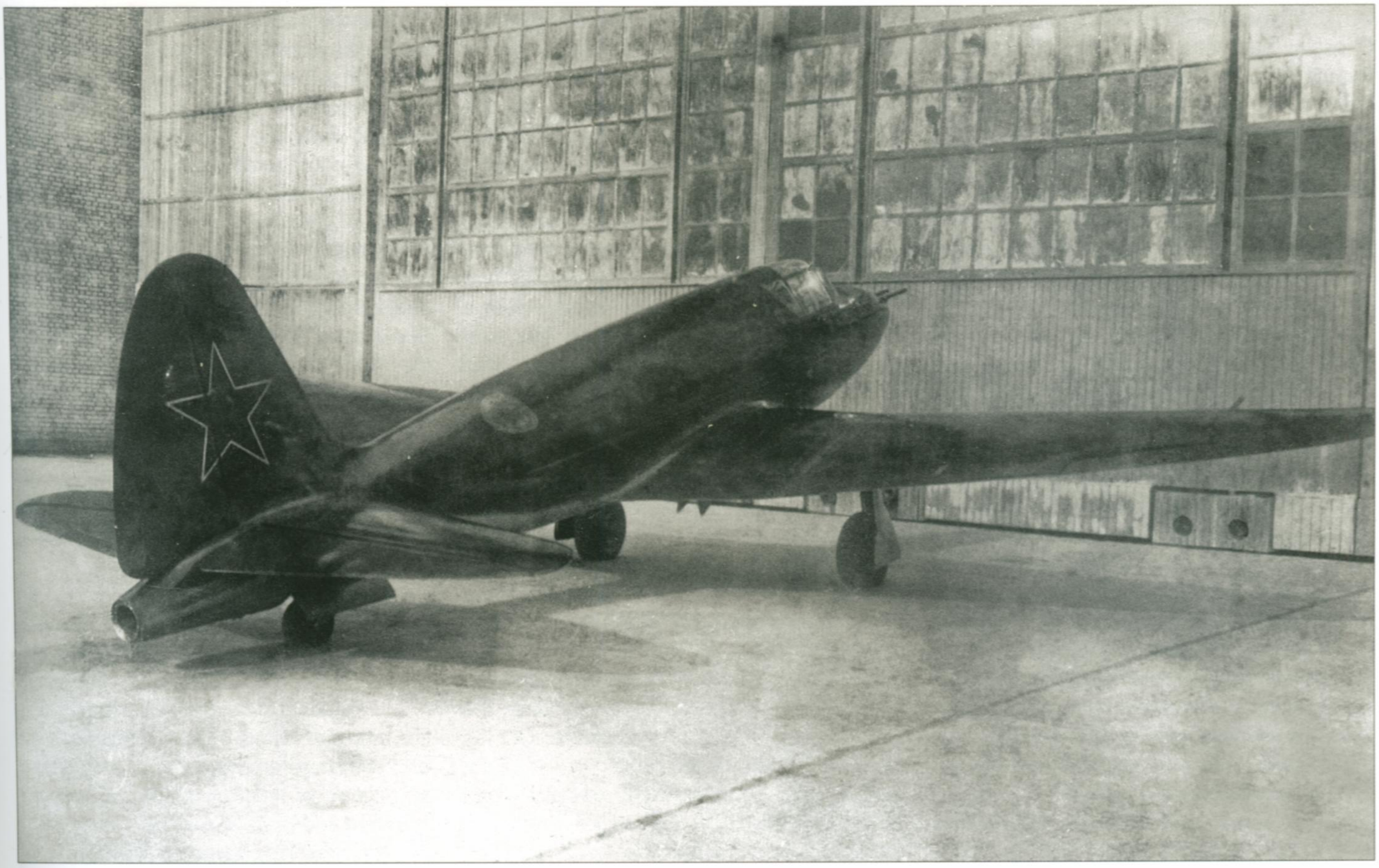
This heavily retouched photo from the design documents shows the '302P' sitting on its undercarriage. The main gear units were quite tall, giving the aircraft a marked nose-up attitude on the ground.



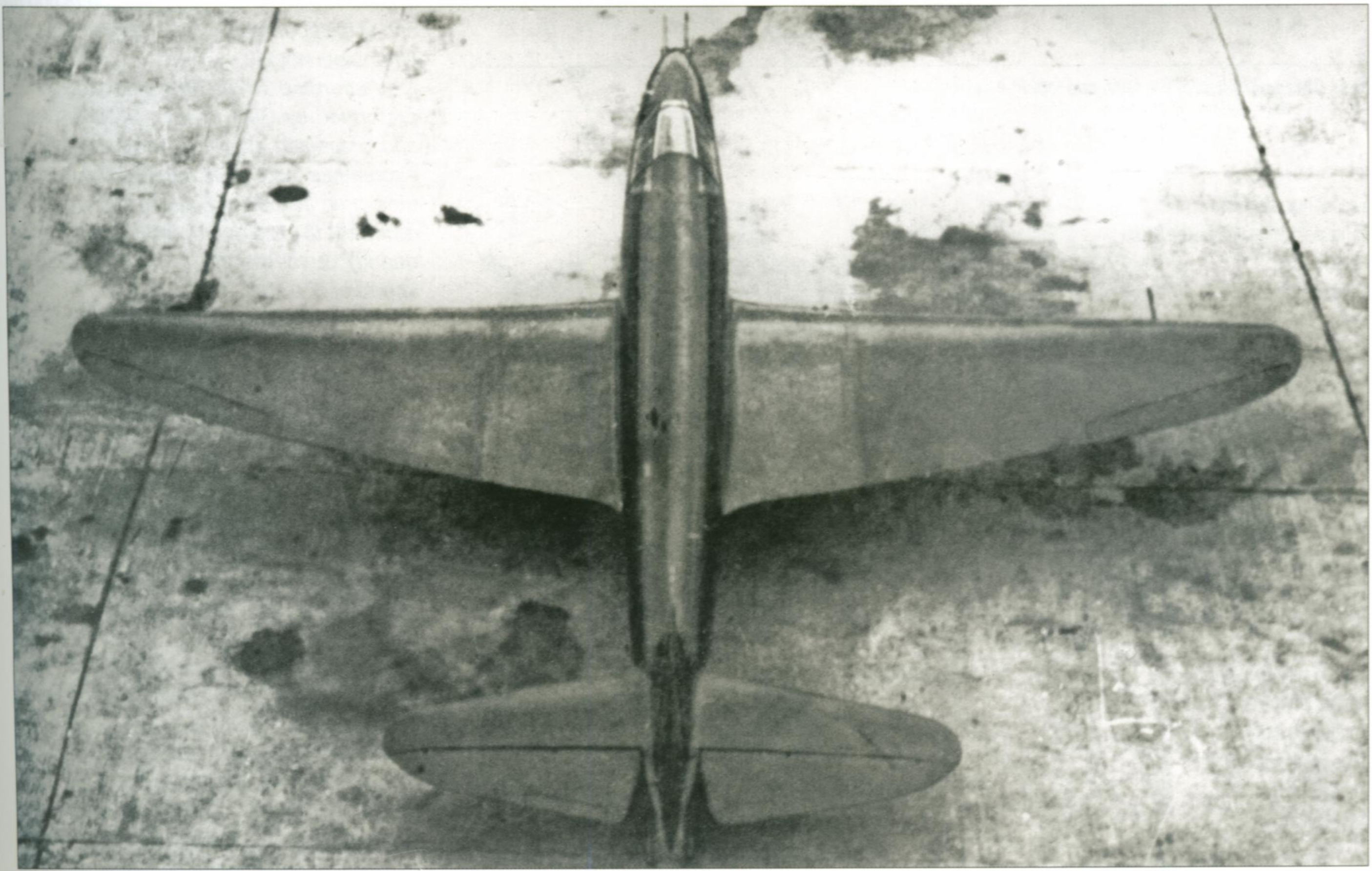
Above: Front view of the '302P' parked in front of one of the hangars at the LII airfield in Ramenskoye.



Rear view of the same aircraft, showing the rocket motor nozzle and the tailwheel well doors.



Above: Three-quarters rear view of the '302P'.



This upper view shows the fighter's strong wing taper.

On 12th November 1943 LII's director A. V. Chesalov sent letter No.676s addressed to Deputy People's Commissar of Aircraft Industry Pyotr V. Dement'yev and containing a report on the institute's activities in October. This document referred, among other things, to the '302' aircraft (in the documents of that time the new designation – '302P' – was often omitted in favour of the usual '302'). It stated that the '302' with no engine installed had performed 12 flights on tow behind a Tupolev SB (ANT-40) bomber during that month; the flights revealed continuous directional oscillations of the aircraft at speeds in excess of 200 km/h (124 mph). The report added that measures intended to eliminate the oscillations (increasing the rudder mass balance and installing rudder compensation flaps, as well as refining the rear fuselage contours) had not produced the desired results and that the institute was 'studying further measures for eliminating the oscillations'.

After this the second prototype of the '302' aircraft was sent to TsAGI where it underwent testing in the T-104 wind tunnel. During these tests the lift/drag ratio of the airframe was determined – and it proved to be as high as 14.6, an unprecedented value!

After some modifications the fighter was again tested in glider configuration, towed by an SB bomber (according to other sources, the engineless interceptor was also towed by a Tupolev Tu-2 and a North American B-25 Mitchell). On 4th October (some sources say 9th October) Sergey N. Anokhin performed the 27-minute first flight in the '302P', which was towed by an SB. Anokhin gave praise to the aircraft, as did test pilots Mark L. Gallai and Boris N. Koodrin. Several dozen flights were performed in the course of the tests. According to the evaluation of flight performance given by Anokhin, the '302P' showed exceptional stability and controllability in all axes, behaved well in a sideslip, was good at performing rolls, and was easy to land after the towing cable was released. Gallai, who did not take part in the testing but had an opportunity to evaluate the '302P' as a check-flight pilot, called the aircraft 'a standard by which other aircraft should be judged'. A similar appraisal was expressed by the second check-flight pilot, B. N. Koodrin, and by project engineer in charge of the testing V. N. Yelagin. The landing speed of 115-120 km/h (71-74.5 mph) recorded during testing was in conformity with the interceptor's normal landing mode. However, there were no powered flights because the rocket motor was still unavailable. On the whole, the tests of the '302P' in the glider version were completed successfully – one of the few problems noted was related to self-induced oscillations of the rudder which manifested themselves during flights; they were eliminated by the installation of a servo actuator.

Yet, the main problem which worried not only to the aircraft's designers but the leaders of the aircraft industry a lot was the machine's extremely short potential endurance which did not allow the '302P' to become a full-fledged combat aircraft. On 22nd October 1943 People's Commissar of Aircraft Industry Aleksey I. Shakhoorin sent a report titled 'On jet-propelled aircraft' to SNK Chairman Gheorgiy M. Malenkov. The report contained an analysis of the state of affairs; in this report Shakhoorin stated that *'...neither the BI nor the '302' are combat aircraft...'* and suggested that *'...GIRT (the Institute for Jet Propulsion Technology, or NII-3) be relieved forthwith of the task of constructing aircraft, and plant No.55 (the Institute's experimental production facility) be reoriented towards the construction of small batches of liquid-fuel rocket motors'.*

On 26th October 1943 a report, titled 'On the endurance of the '302' aircraft, designed by Kostikov, at the specified altitude' was prepared. The report stated, among other things:

'...Pursuant to the State Defence Committee decision dated 26.VII.42, Kostikov's aircraft shall have an endurance of 20 minutes at an altitude of 8,000 m [26,240 ft] and at a speed of 800 km/h [496 mph].

At a meeting chaired by Malenkov in the Communist Party Central Committee, Kostikov quoted a different figure of the aircraft's endurance at the specified altitude (8,000 m) and at the specified speed (800 km/h), namely 8 minutes, not 20.

According to aerodynamic calculations performed by GIRT (that is, by NII-3 – *Auth.*) *and presented after a meeting at TsAGI, the aircraft has the endurance of a mere 5.3 minutes at an altitude of 8,000 m and at a speed reduced to 725 km/h [451 mph]; consequently, it will be still less at the specified speed of 800 km/h, namely:*

a) with engine characteristics as given in the aerodynamic calculations by GIRT:

2.7 minutes;

b) with engine characteristics as determined by tests at NII VVS:

1.61 minutes.

Kostikov has not yet submitted to NKAP a report from GIRT on the testing of an improved version of the engine; thus, it has not been possible to check the correctness of the data adopted by GIRT in its aerodynamic calculations.

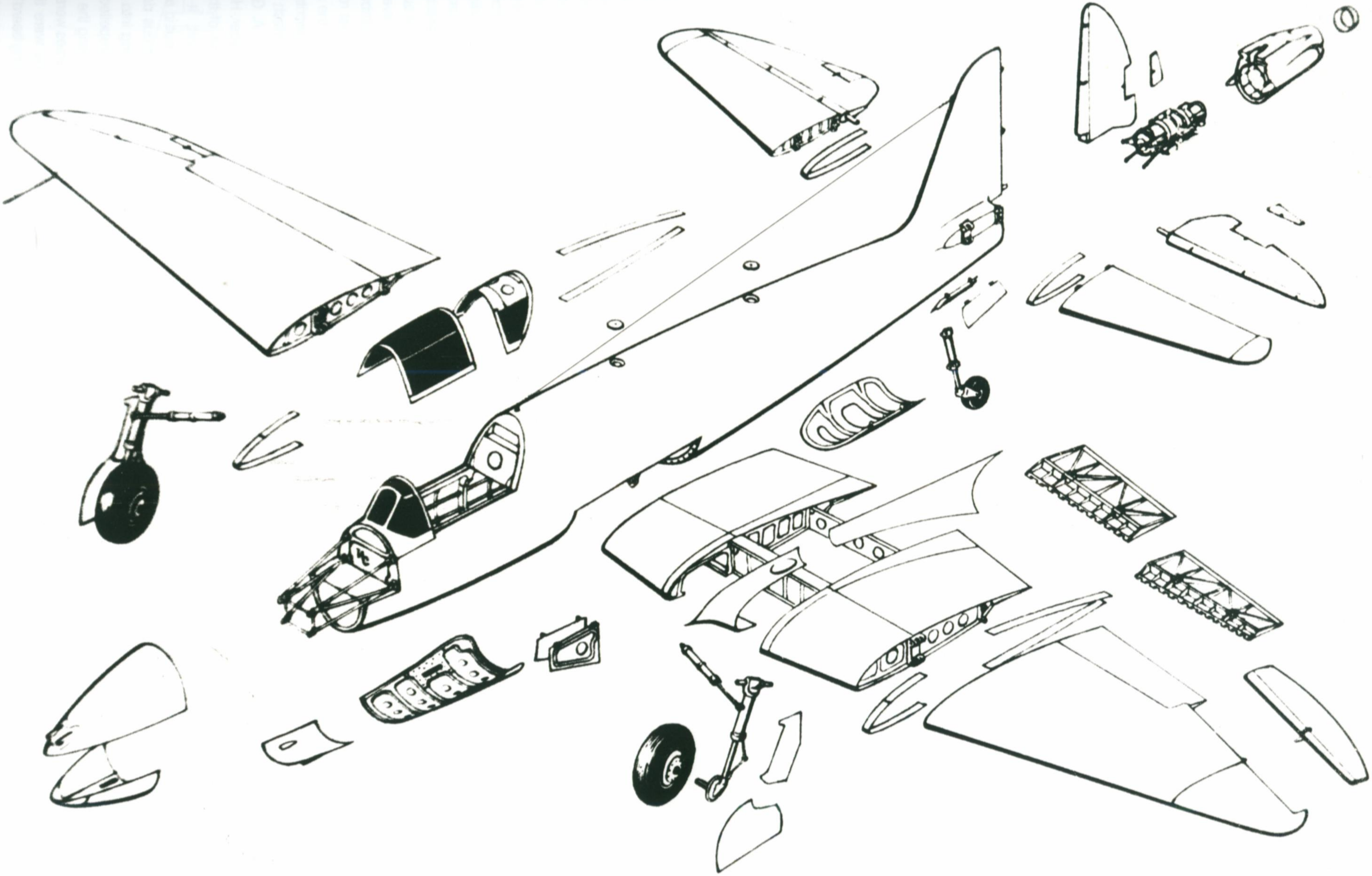
But, even if one proceeds from the calculations made by GIRT, Kostikov's aircraft will have an endurance of not more than 2.7 minutes instead of the 20 minutes specified by the State Defence Committee.'

While discussions were going on as to the expediency of further work on rocket-propelled interceptors at large, preparations for prototype construction were nevertheless

Main Characteristics of the '302' and '302P' Aircraft

	'302'	'302P'
Year of manufacture	1942	1943
In-house designation in the OKB	Ko-1	Ko-3
Powerplant	RD-1400 + 2 ramjets	RD-2M3
Length, tail up	n.a.	8.7 m (28 ft 6½ in)
Wing span	11.1 m (36 ft 5 in)	9.55 m (31 ft 4 in)
Stabiliser span	n.a.	3.4 m (11 ft 1⅞ in)
Wing area, m² (sq ft)	19.2 (206.7)	14.8 (159.3)
Empty weight, kg (lb)	n.a.	1,502 (3,312)
Fuel weight, kg (lb)	n.a.	505 (1,113.5)
Oxidiser weight, kg (lb)	n.a.	1,230 (2,712)
All-up weight, kg (lb)	n.a.	3,358 (7,404)
Maximum speed, km/h (mph)	900 (559)	800 (497)
Unstick speed, km/h (mph)	n.a.	200 (124)
Time of acceleration to 600 km/h (373 mph), sec	n.a.	34
Time to altitude, minutes	2.0 (H=9,000 m/29,520 ft)	2.1 (H = 5,000 m/16,400 ft) 2.8 (H = 9,000 m/29,520 ft)
Service ceiling, m (ft)*	9,000 (29,520)	18,000 (59,040)
Range, km (miles)*	n.a.	100 (62)
Endurance, hours*	2.0	0.5
Time of take-off run, sec*	n.a.	16-18
Armament	4 x ShVAK-20 cannon	4 x ShVAK-20 cannon
Ammunition load	400 rounds	400 rounds

* Manufacturer's estimates



An exploded view of the '302P' interceptor.

begun. For example, on 3rd November 1943 NKAP issued order No.666s which obliged Plant No.464, where the rocket-propelled aircraft was originally to be built, to transfer its jigs and tooling for the '302' to NII-3. On 23rd November A. G. Kostikov, Director and Chief Designer of NII-3 under SNK (*sic* – that was the Institute's name used in the document; this corroborates the fact that the institute was subordinated directly to the Government) wrote to People's Commissar of Aircraft Industry A. I. Shakhoorin, asking him to order the director of Plant No.464 to *'complete the assembly of subassemblies of the 'object No.'302P' (wings and tail surfaces) for the third flying example, and then to conduct the transfer of the jigs and tooling in accordance with order No.666s dated 3 November 1943…'*. Less than two weeks later, on 4th December, Shakhoorin wrote back. In his letter No.N-30/4859 he informed Kostikov that *'…plant No.464 has fulfilled the task of assembling the units'*. The plant could not manufacture the subassemblies for the fourth example of the '302P', being overburdened with other tasks. All jigs and tooling for the '302P' interceptor had been sent to NII-3 in compliance with the Order No.666s.

In the meantime Kostikov, as the chief of the institute and the leader of the work on the rocket-propelled interceptor, was well aware that failure to attain the specified performance (especially as regards endurance) was fraught with peril both to the aircraft itself and to its designers (with all the consequences determined by wartime conditions – after all, it was a failure to fulfil an important task posed by the State Defence Committee). In these circumstances, he decided to take the initiative into his own hands. On 6th December 1943 he sent a report to G. M. Malenkov, Chairman of the Council of People's Commissars, in which he admitted the insufficient endurance of the '302' aircraft. He also suggested that the possibility of 'aerial aircraft carriers' – that is, 'mother ships' for rocket-propelled interceptors – should be considered. However, in the harsh wartime conditions such 'fantasies' obviously could not find support. Although the work on the rocket-propelled interceptor was still going on both at the institute and at the production facility, storm clouds began to gather above NII-3 and its leader.

In the winter of 1944 the '302P' fitted with a ski undercarriage made its one and only flight under its own power. Eyewitnesses recounted that the flight was generally successful, but one of the undercarriage legs failed on touchdown and the aircraft slewed, ending up in a snowdrift beside the runway. However, already some time before that, when the rocket motor was ready for installation in the flight-tested airframe of the '302P' prototype, NKAP had nevertheless taken a decision to terminate the '302' programme. Officially this decision was motivated by the availability of a small batch of BI interceptors and by the lack of a requirement for a short-range rocket-propelled interceptor on the part of the front-line aviation and the Air Defence aviation.

Views have been expressed that the programme was actually terminated for several other reasons and that the decision to close it down was instigated by many prominent figures in the Soviet aircraft industry of that time who lived in an atmosphere of incessant backstage intrigues and were themselves instrumental in fanning this atmosphere. What had really happened? After all, a new two-chamber rocket motor was under development for the third prototype, which promised an increase of endurance at combat altitude to 3.5 minutes. True, this figure also fell utterly short of Kostikov's initial promises and was absolutely unsatisfactory for the military. The deadlines for the presentation of results had passed long ago, the clouds were gathering, and in early 1944 'the storm broke', as one puts it in Russia. A commission was formed to investigate the activities of NII-3; it was headed by Deputy People's Commissar of Aircraft Industry Aleksandr S. Yakovlev and included, as one of its members, L. M. Gaidukov, member of the Military Council of Guards Rocket Launcher units.

Indeed, the tactical capabilities of the '302P' interceptor were very poor – as were the capabilities of the BI aircraft, for that matter. In fact, these machines (which were, for all practical purposes, experimental aircraft) became the first step towards the investigation of high subsonic speed aerodynamics by means of real hardware; they could have become platforms for the development of new liquid-fuel rocket motors. However, the military and the aircraft industry needed tangible results, especially in wartime conditions.

The customers did not make official complaints about the aircraft, which had confirmed its ability to fly well in the glider version. As noted earlier, the failure to comply with the development schedule of the '302P' interceptor was due first and foremost to setbacks in the development of the engines. However, the findings of the commission investigating the activities of the Institute served as a basis for punitive measures. True, the anger of the top brass did not affect the designers responsible for the airframe (M. R. Bisnovat and others); on the other hand, it fell with all its force on the leader of the institute, A. G. Kostikov, who was relieved of his duties and arrested on 15th March 1944. In addition to the ousting of Kostikov, other measures were taken; in particular, the Research Institute for Rocket Propulsion Technology (NII-3) was transformed into the Research Institute of Jet Aviation and subordinated to NKAP. The new institute came to include Plant No.293 based in Khimki, a northern suburb of Moscow (before the war this plant had served as a base for the OKB led by Viktor F. Bolkhovitinov). In May 1944 the institute was renamed NII-1, and the development of turbojet and rocket motors for aircraft became its main task. In due course this work was taken over by well-established aero-engine enterprises and the newly founded OKB-165 headed by Arkhip M. Lyul'ka, while the specialists of NII-1 concentrated their activities on applied scientific research and on the fulfilment of special design tasks associated with enhancing the development of aircraft and rocket technology.

By that time liquid-fuel rocket motors serving as auxiliary boosters were installed on the Yak-3 and La-7 fighters. In May 1944 the OKB-51 design bureau led by Nikolay N. Polikarpov was tasked with the development of a new rocket-propelled interceptor powered by the RD-2M3 engine; the aircraft was dubbed Malyutka (see next chapter). Furthermore, development of the ramjets mentioned above was also completed and they passed a test cycle on the sixth prototype of the BI interceptor (BI No.6).

Finally, one more thing to which the author would like to call attention in this chapter. Discussions arose from time to time in the Russian (and previously Soviet) press as to who was in actual fact the designer (that is to say – the author) of the '302' aircraft? The enterprise where the aircraft was being developed was led by A. G. Kostikov, the design work initially proceeded under the direction of M. K. Tikhonravov, the '302P' version was developed directly by a team led by M. R. Bisnovat… In various books on aviation history one can see all three of these persons mentioned as the author of the aircraft in question. Indeed, every one of these well-known persons contributed much effort to the creation of a Soviet rocket-powered interceptor. In the USSR the authorship of an aircraft was usually ascribed to the leader of the design team in which the aircraft was developed. In this case A. G. Kostikov played the role of such a leader. His conduct in the capacity of the leader of the institute was fairly controversial, yet, it must be acknowledged that he had put in much effort (as corroborated by numerous documents) for the purpose of translating into reality the idea of creating a rocket-propelled interceptor. On the other hand, among the leaders of design bureaux whose names were borne by Soviet aircraft, how many were those who actually stood at the drawing board? It is up to the reader to judge…

Chapter 3

The Stillborn 'Baby'

Wartime Soviet Projects

Yak-7R Interceptor

Aleksandr Sergeyevich Yakovlev, who had developed a family of piston-engined fighters with excellent characteristics during the war years, was not enthusiastic about the liquid-fuel rocket motors, which at that time were still 'green', as one used to say (that is, beset by teething troubles). However, he certainly could not keep aside from the development of high-speed and high-altitude aircraft – by virtue of his position he was obliged to join in. The project of one of the 'pure-jet' versions of the Yak-7 fighter (it was designated Yak-7R, the R standing for *reak**tiv**nyy* – jet-propelled) was completed on 27th August 1942. The project envisaged installing two DM-4S ramjets designed by I. A. Merkoolov under the wings; they were to be supplemented by a D-1-A liquid-fuel rocket motor (developed by Leonid S. Dooshkin) accommodated in the rear fuselage, which required the rudder to be cut away at the base. The cockpit was moved forward, its original position being occupied by fuel and oxidiser tanks; a parabolic fairing replaced the original cowling of the Klimov VK-105 piston engine and the propeller spinner. The overall length of the fighter was slightly increased as compared to the piston-engined version. It was presumed that the liquid-fuel rocket motor would be used for take-off (for accelerating the aircraft until the cruise ramjets could be ignited), during climb and in those cases when it was necessary to catch up with an enemy aircraft.

The project did not proceed further than the drawing board because reliably working ramjets were unavailable, and Dooshkin's engines produced in just a few examples were allocated for installation in the BI aircraft. Nevertheless, Yakovlev, who was at the height of his career at the time, had his share of the complex technical problems posed by liquid-fuel rocket motors on aircraft. As mentioned earlier, test pilot V. L. Rastorgooyev was killed in a crash when testing the Yak-3RD experimental fighter equipped with the RD-1KhZ rocket booster.

Malyutka Rocket-Propelled Interceptor (Aircraft 'Sh', *Izdeliye* 51)

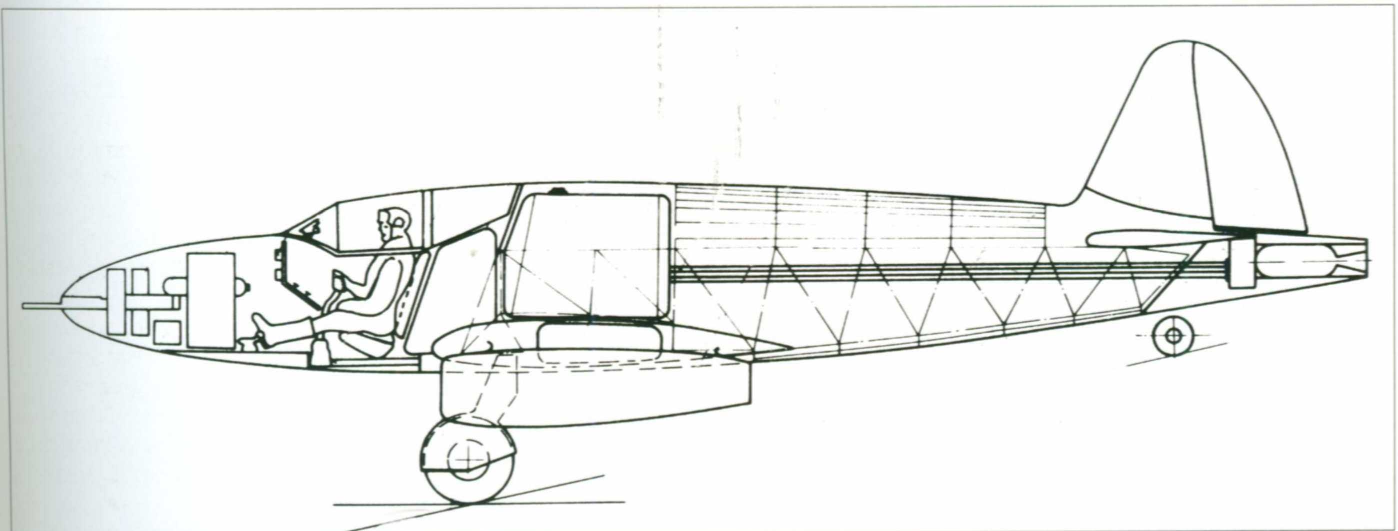
Nikolay Nikolayevich Polikarpov, a famous Soviet aircraft designer, happened to be one of the design bureau chiefs who were involved in the development of high-speed, high-altitude rocket-propelled aircraft during the Great Patriotic War. The requirement calling for the development of an 'air defence interceptor-fighter for short-duration action' (that was the wording used in documents) was issued to Polikarpov's OKB-51 in late 1943, and the design work started in 1944. In the OKB the new fighter was given the in-house designation 'aircraft Sh' or *izdeliye* (article) 51. Informally, however, it was known as the *Malyutka* (Little one, or Baby).

Several versions of the aircraft's layout were considered; one of them, described below, was proposed after N. N. Polikarpov had passed away. This version was developed under the direction of Deputy Chief Designer Dmitriy L. Tomashevich in one of the sections of the general arrangement team (the section was headed by A. M. Polyakov and the team as a whole by L. P. Korotkov).

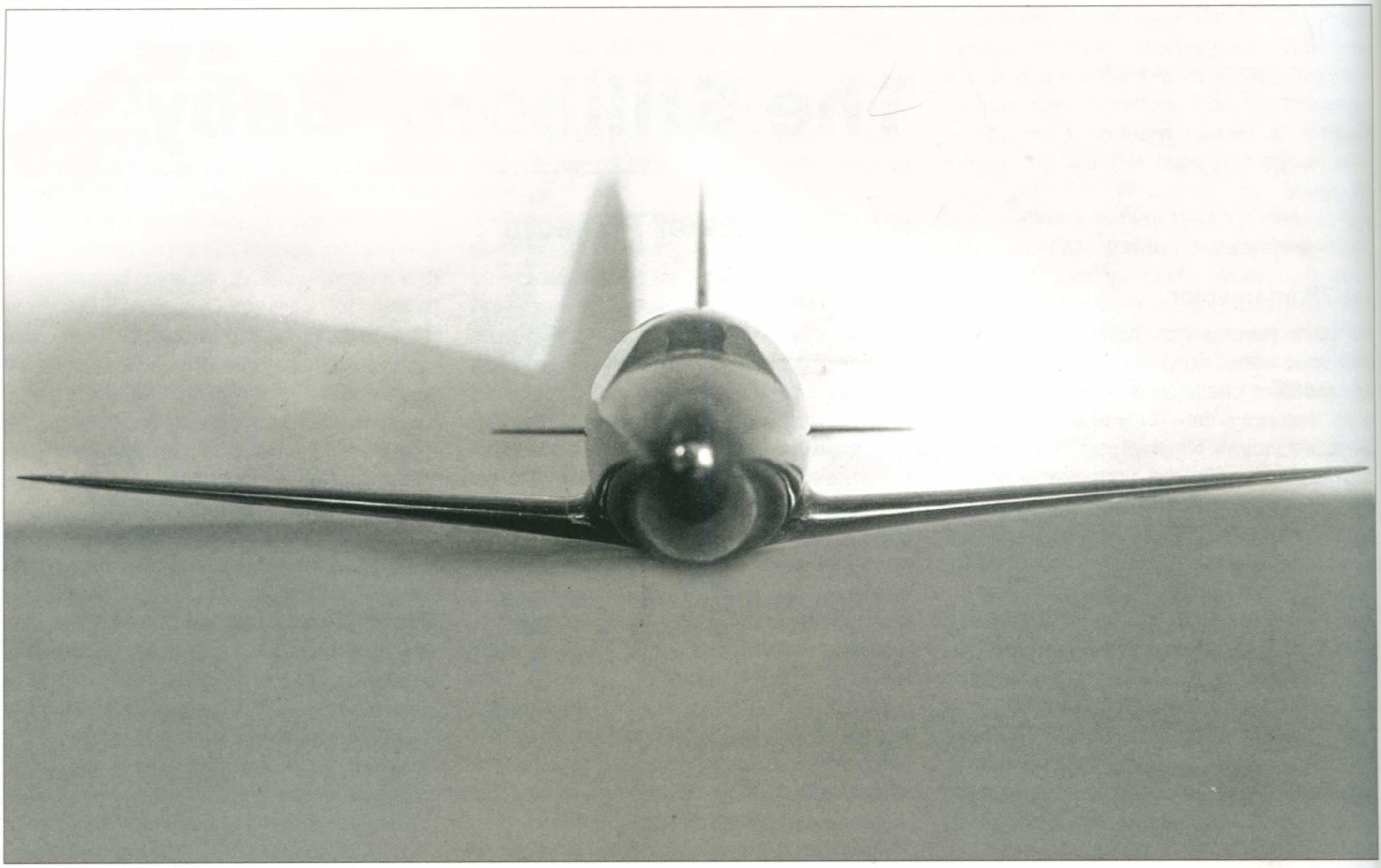
Initially the designers planned to install an RD-1100 liquid-fuel rocket motor (that was the designation initially used in documents; in actual fact, it referred to the D-1A-1100 engine designed by L. S. Dooshkin at NII-1) with a thrust of some 1,100 kgp (2,425 lbst). Later plans envisaged the use of the RD-2M3V liquid-fuel rocket motor developed by the same designer; this engine featured a fuel pump and ran on kerosene and nitric acid.

The rocket-propelled interceptor was a sleek monoplane with low-set cantilever wings. The fuselage of wooden construction with plywood skin comprised forward and aft sections. The all-metal wings were joined to the forward fuselage. The two-spar all-metal horizontal tail was attached to the rear fuselage; the fin was built integrally with the rear fuselage structure. The cockpit had an extensively glazed hinged canopy which afforded a good field of view. The armament comprised two 23-mm (.90 calibre) cannons located well aft under the cockpit, with a total ammunition complement of 200 rounds.

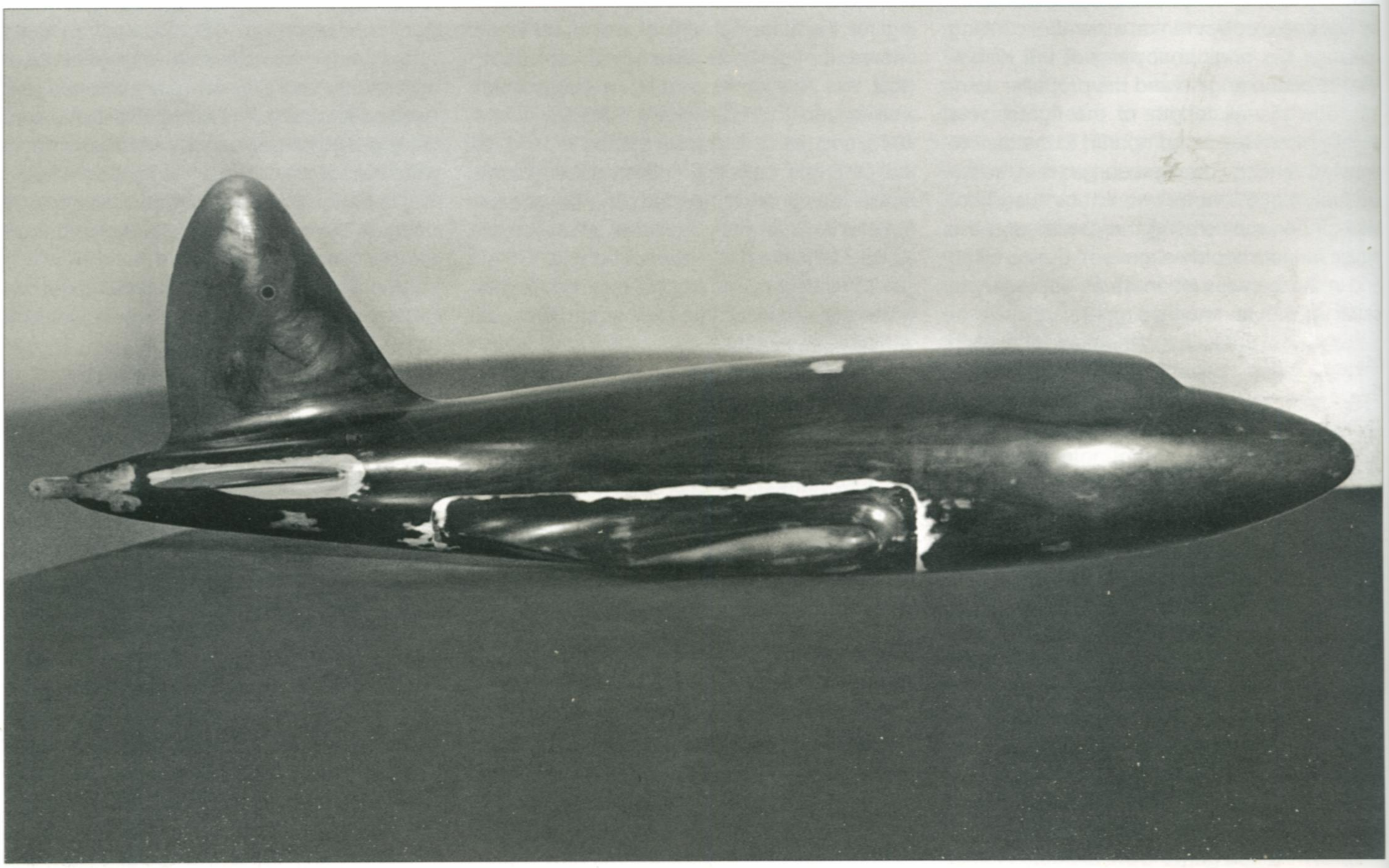
The fighter featured a tricycle undercarriage with an aft-retracting nosewheel and



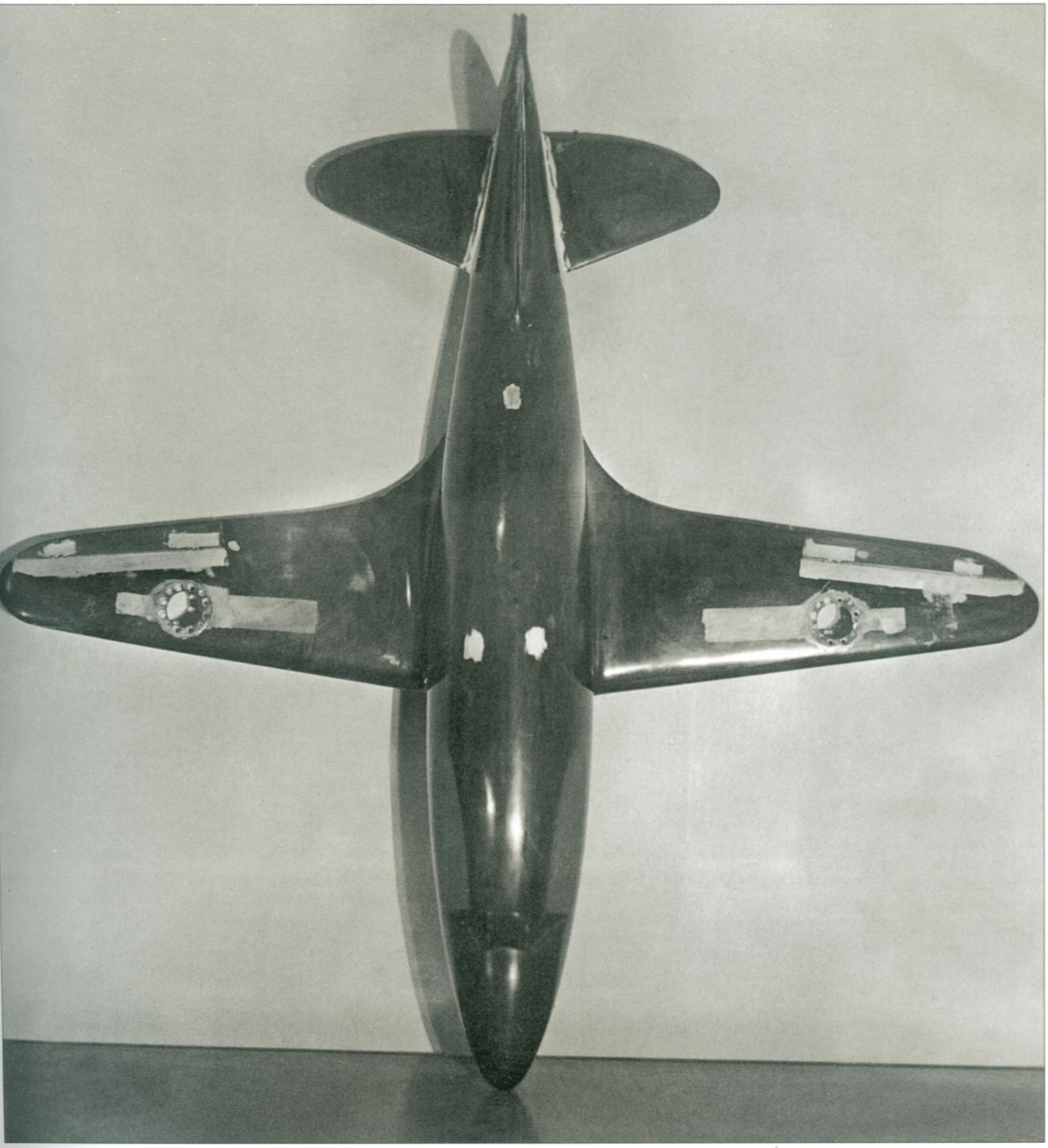
A cutaway drawing of the projected Yak-7R interceptor showing the underwing cruise ramjets, the aft-mounted rocket booster, the fuel and oxidiser tanks for it amidships, and the pipelines passing through the fuselage truss.



Above: Front view of a wooden wind tunnel model of Polikarpov's projected 'aircraft Sh' or Malyutka rocket-powered interceptor.



A side view of the same model; the Malyutka was a short and tubby little aeroplane.



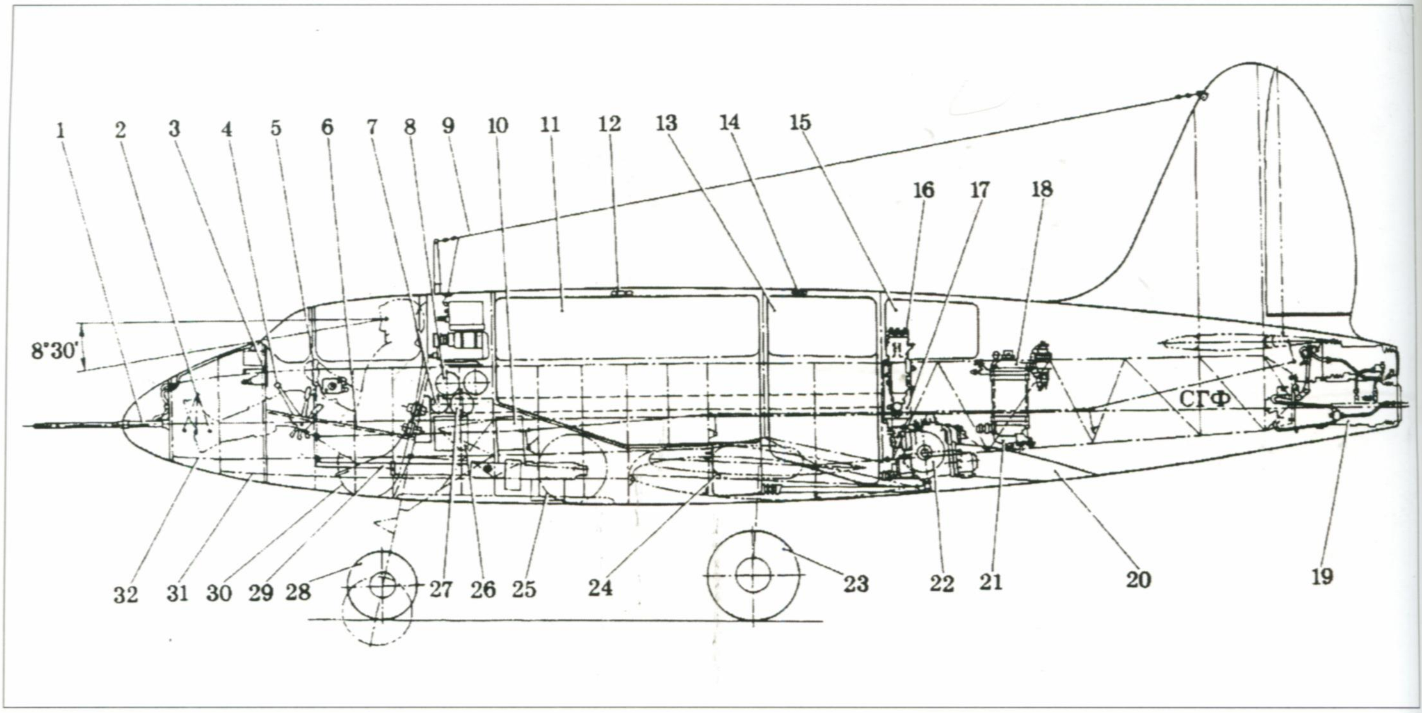
Upper view of the same model. The metal fittings in the wings are for the attachment pins securing the model in the wind tunnel.

inward-retracting mainwheels. Located above the mainwheel wells were two tanks holding the kerosene fuel and the nitric acid used as the oxidiser. A slight shift of the CG caused by the consumption of the fuel and oxidiser was compensated by discharging water from a special tank. The engine's two combustion chambers allowed the aircraft to take off and accelerate to maximum speed (the bigger chamber) and maintain this speed (the smaller chamber). Having intercepted the target, the aircraft was to make a gliding descent to base with the engine switched off, eventually with a fuel reserve of 80 kg (176 lb). The powerplant itself was mounted on an all-weld steel frame. All accessories and equipment could be easily accessed through hatches.

The work on this project continued until late 1944. Subsequently the design personnel, by that time headed by V. N. Chelomey, switched to the development of pulse-jet-powered cruise missiles – the first of their kind in the Soviet Union.

RM-1 (SAM-29) Supersonic Interceptor

At the beginning of the Great Patriotic War Aleksandr Sergeyevich Moskalyov, a well-known Soviet aircraft designer, held the posts



Cutaway Drawing Key of Malyutka (*izdeliye* 'Sh') Interceptor, Version 1

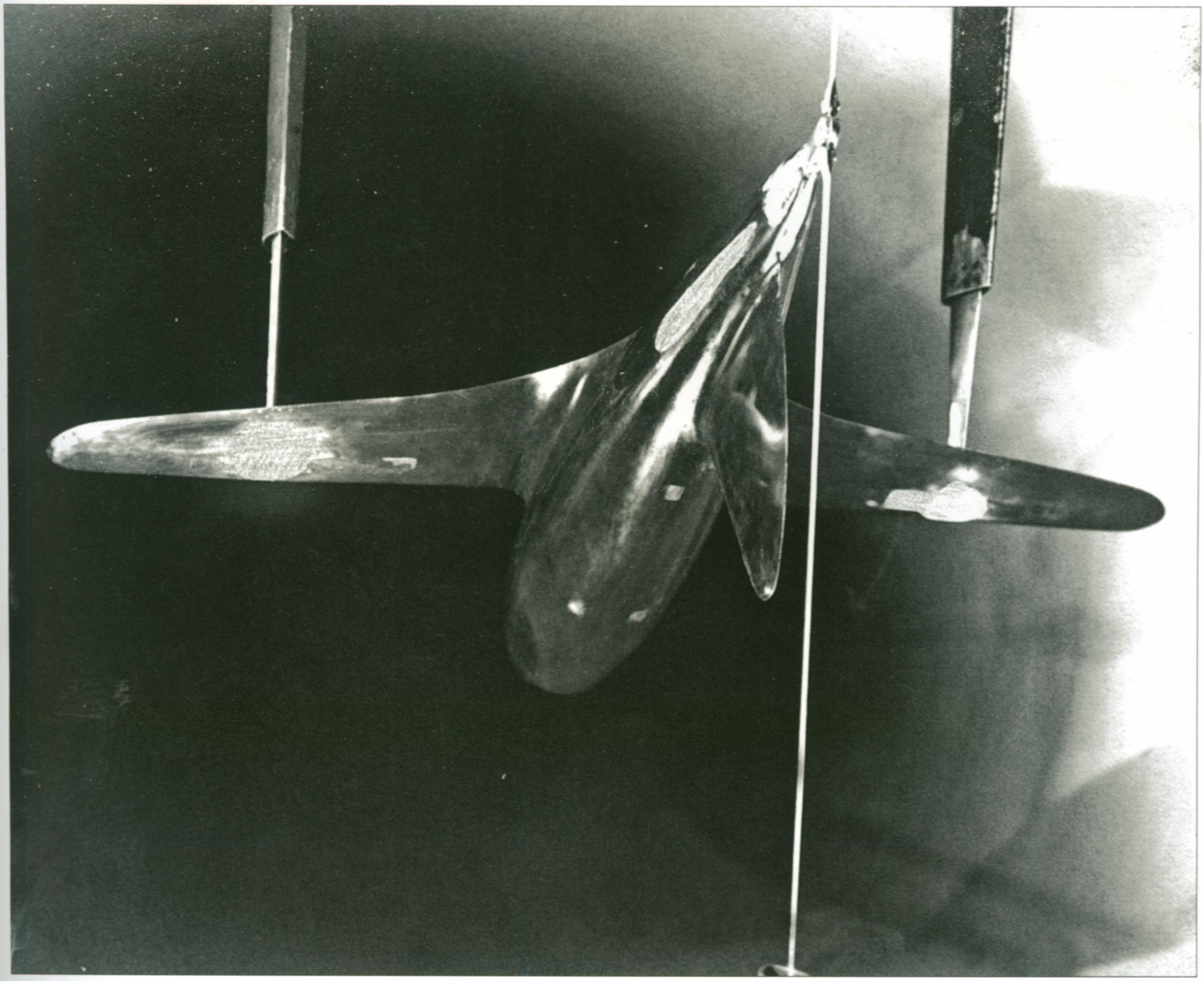
1	Pitot tube
2	Rudder pedals
3	Instrument panel
4	Throttle lever
5	Control stick
6	Port and starboard cockpit consoles
7	Oxygen bottle
8	Compressed air bottles for landing gear actuation
9	Aerial
10	Ammunition boxes
11	Nitric acid tank, 800 litres (176 Imp gal)
12	Nitric acid tank filler cap
13	Kerosene tank, 400 litres (88 Imp gal)
14	Kerosene tank filler cap
15	Water ballast tank, 75 litres (16.5 Imp gal)
16	Steam/gas generator
17	Start-up bottle for kerosene
18	Start-up bottle for oxidiser
19	Liquid-fuel rocket motor
20	Turbopump exhaust pipe
21	Actuating bottle for the water tank
22	Turbopump assembly
23	500 x 180 mm (20.4 x 7.35 in) mainwheel
24	Mainwheel (retracted)
25	Nosewheel (retracted)
26	12A30 storage battery
27	Compressed air bottle for the engine
28	390 x 170 mm (15.9 x 6.9 in) nosewheel
29	23-mm cannon (two)
30	Pilot's seat
31	A stringer's axis
32	A longeron's axis

Design Performance of the Malyutka Interceptor

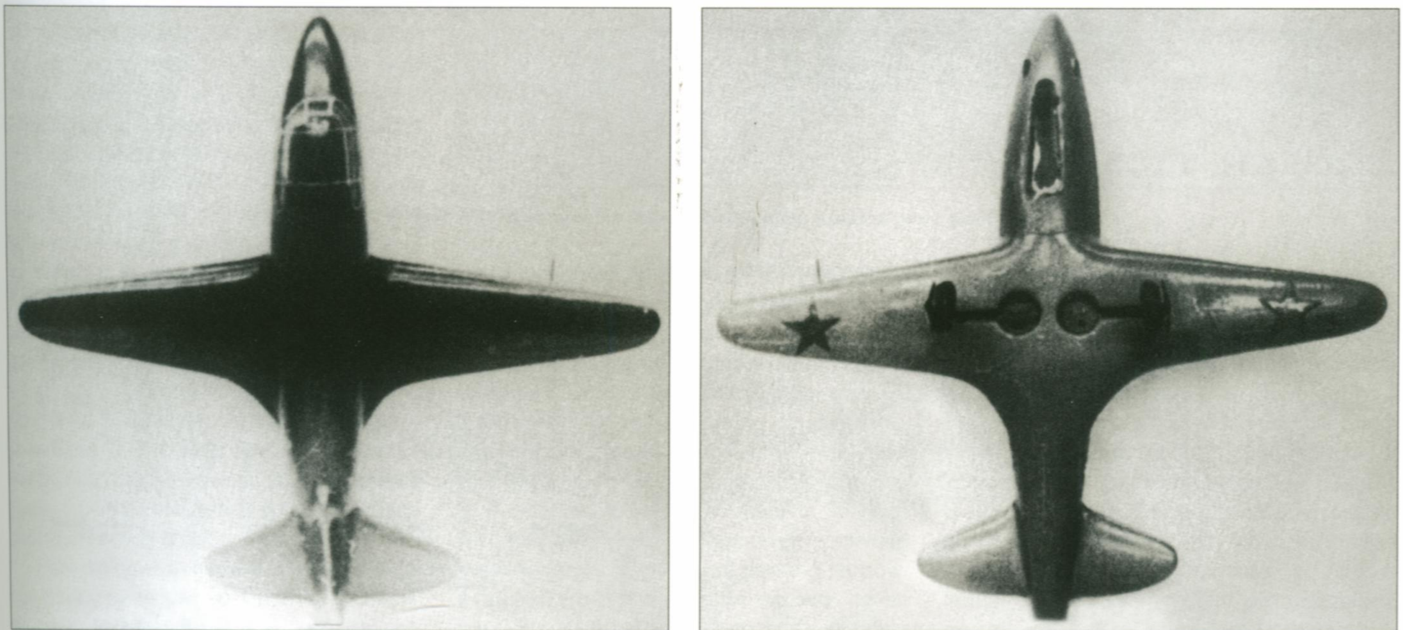
	Initial project	Modified project
Engine	RD-1100	RD-2M3V
Nominal thrust, kgp (lbst)	1,100 (2,425)	1,400 (3,087)
Length	7.3 m (24 ft 0 in)	7.0 m (23 ft 0 in)†
Height	3.15 m (10 ft 4 in)	3.07 m (10 ft⅞ in)
Wing span	n.a.	7.5 m (24 ft 7 in)
Wing area, m^2 (sq ft)	6.0 (64.6)	8.0 (86.1)
Horizontal tail span	3.0 m (9 ft 10 in)	3.0 m (9 ft 10 in)
Wheel track	2.11 m (7 ft 0 in)	2.07 m (6 ft 9½ in)
Wheelbase	2.14 m (7 ft 0 in)	2.02 m (6 ft 7½ in)
Ground angle	n.a.	–1°
Empty weight, kg (lb)	n.a.	1,016 (2,240)
Total weight of propellants, kg (lb)	n.a.	1,575 (3,473)
Total useful load, kg (lb)	n.a.	1,779 (3,923)
Take-off weight, kg (lb)	2,550 (5,620)	2,795) (6,163)
Flight speed, km/h (mph):		
at sea level	n.a.	890-925 (553-575)*
at 5,000 m (16,400 ft)	n.a.	875-900 (544-559)*
at 15,000 m (49,210 ft)	n.a.	845-875 (525-544)*
Landing speed, km/h (mph)	n.a.	135 (84)
Vertical speed, m/sec (ft/min)	100 (19,690)	n.a.
Time to altitude, min		
to 5,000 m	n.a.	1.0
to 15,000 m	n.a.	2.5
Service ceiling, m (ft)	16,000 (52,480)	16,000-18,000 (52,480-59,040)*
Maximum range at 5,000 m, km (miles)	n.a.	95
Endurance, minutes	15	n.a.
Take-off run, m (ft)	n.a.	525 (1,720)
Landing run, m (ft)	n.a.	300 (984)
Armament	Two 23-mm cannons	
Ammunition load, rounds	2 x 100	

* Optimum configuration (zero fuel reserves at landing)

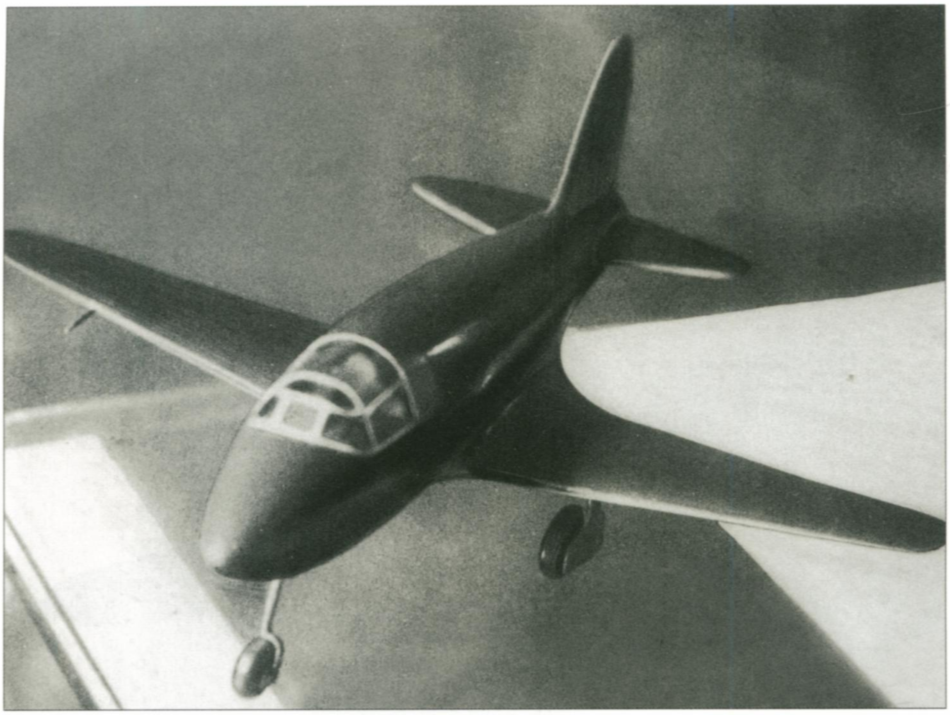
† Less pitot

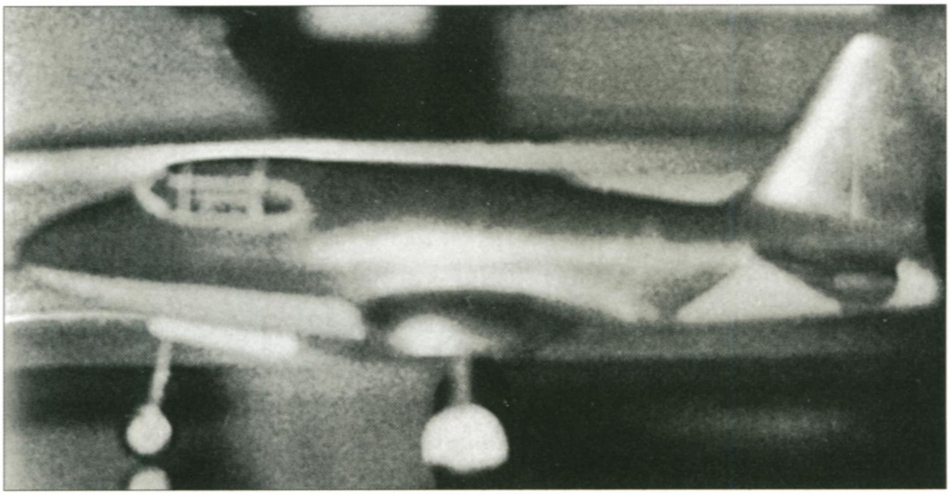


Above: The same model suspended upside-down in one of TsAGI's wind tunnels. The cable attached to the rear fuselage can be moved up and down to adjust the angle of attack. For some reason the horizontal tail has been detached.



Upper and lower views of a display model of 'aircraft Sh' (Malyutka). The large cockpit canopy and the wheel wells are clearly visible.





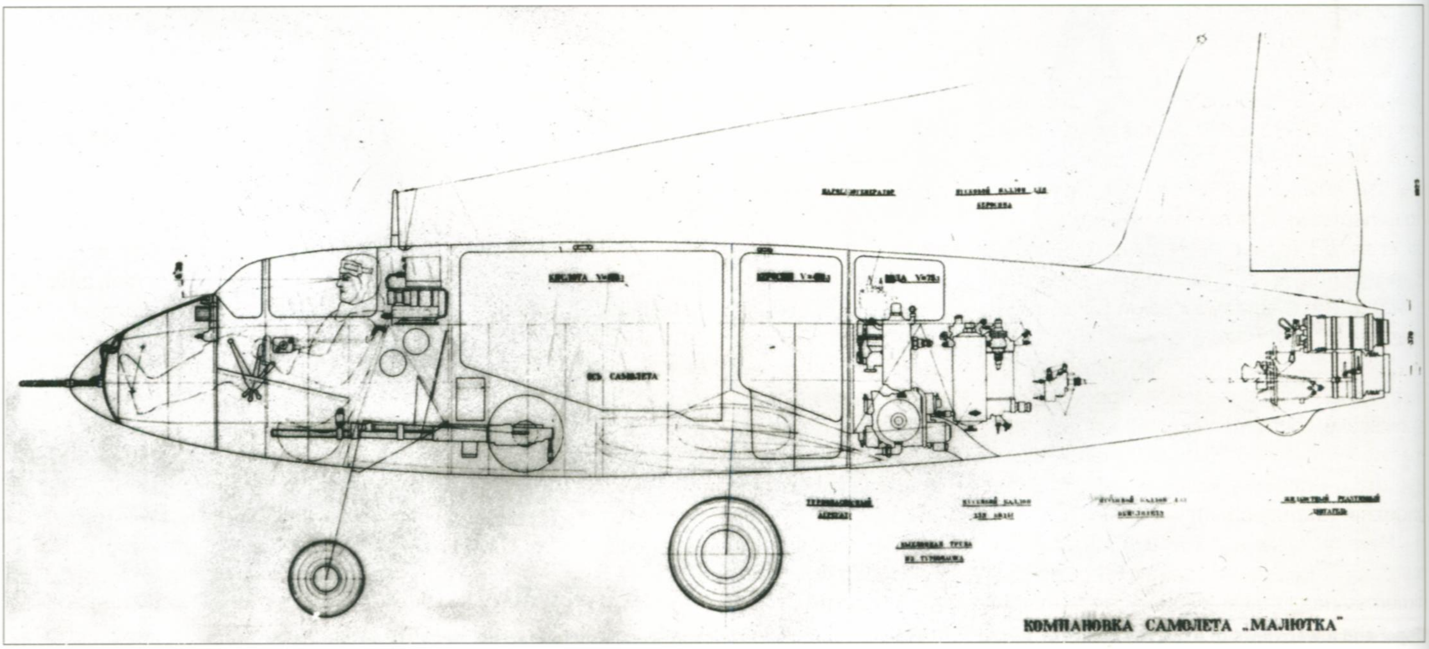
of director and chief designer of Plant No.499 in Siberia (the plant was part of the NKAP framework). It was then that he was entrusted with manufacturing a pre-production (service test) batch of the BI rocket-propelled interceptor which was undergoing flight test at that time. While the testing went on, the plant set about manufacturing the aircraft. However, when production had just begun the third prototype crashed, killing test pilot Grigoriy Ya. Bakhchivandzhi, and further production was suspended. As Moskalyov wrote in his memoirs, even many years after the war he still had no clear idea as to why production of the first Soviet jet aircraft had been stopped. After all, even before the flights of the BI began, it had been known that this aircraft featuring a traditional aerodynamic layout by the day's standards might very probably enter an area of shock stall, especially if one did not watch the speed with utmost attention. It was already known that aircraft featuring a conventional layout might be prone to entering an uncontrollable dive.

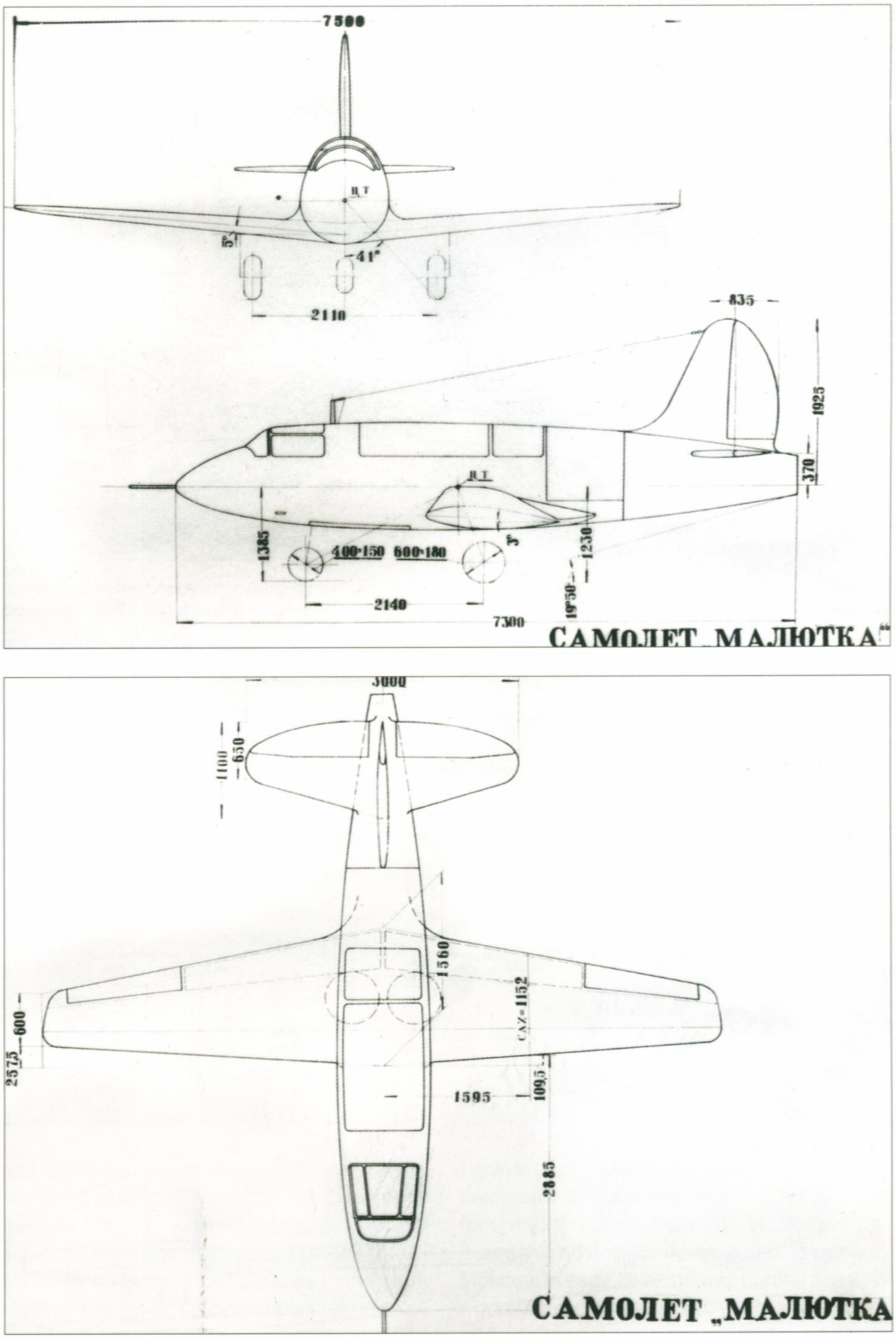
The emergence of a rocket-propelled fighter made Moskalyov come back to his previous projects – the Sigma and Strela (Arrow) aircraft. With Dooshkin's RD-2M3V rocket motor in mind he, too, started projecting a supersonic interceptor, albeit as a 'per-

Above left: Another view of the same model. The name Malyutka was an apt one, as the fighter was indeed very compact; the size of the cockpit provides scale in this view.

Left: The Malyutka sat high above the ground on its stalky undercarriage. Note the canopy side windows providing a measure of rearward view.

Below: A cutaway drawing of the 'aircraft Sh' (Malyutka) interceptor from the ADP documents.





A three-view of the Malyutka interceptor from the project documents.

sonal venture'; the project was designated RM-1 or SAM-29. However, after the crash of the BI aircraft Moskalyov was warned by NKAP that it would be inopportune to propose a new project, especially a project featuring an unconventional layout.

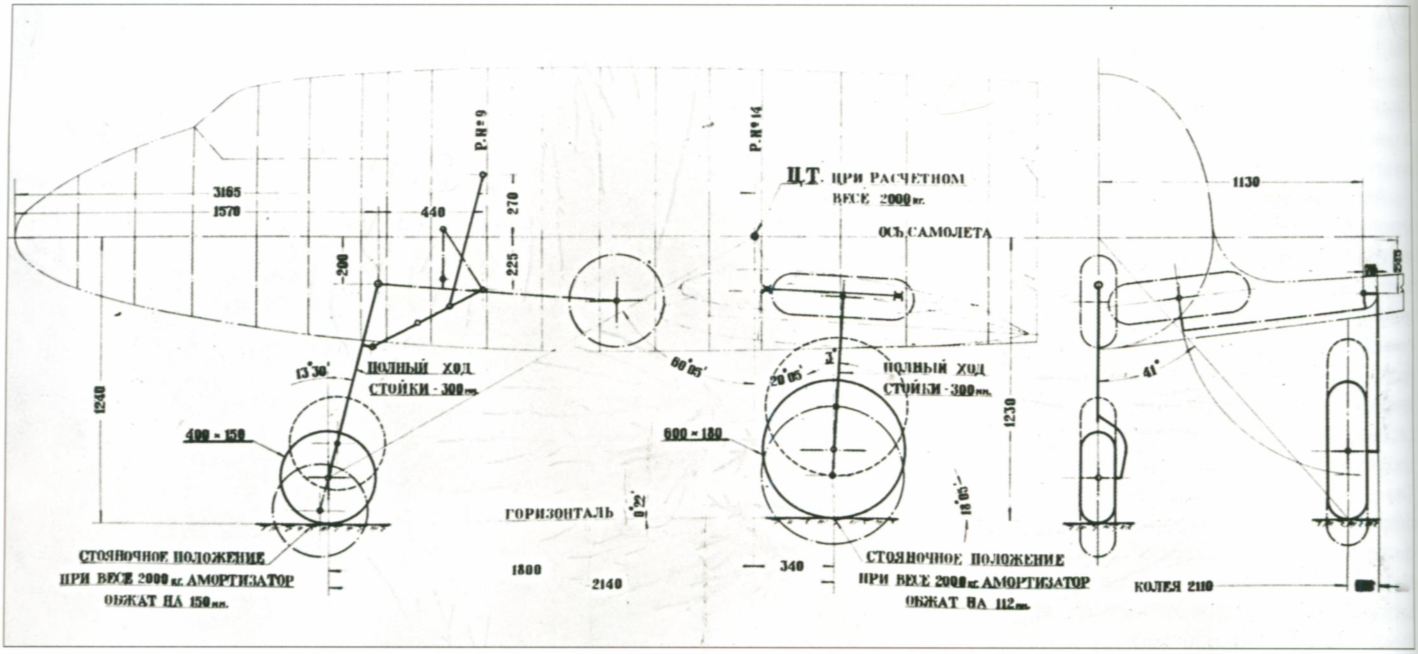
After the war the designer returned to Voronezh where he had started his design activities – on the assumption that his design team would return to that city too. He started looking for suitable premises for his plant; however, everything in the city lay in ruins. A month later, NKAP issued an order under the terms of which the plant was to move to Leningrad and take up residence in the half-destroyed premises of aircraft plant No.237. The plant was situated close to the city's defence line, and no more than 25% of its production facilities remained intact. When Moskalyov's plant moved from Siberia to Leningrad, the staff that followed the plant to the new place included not only former inhabitants of Voronezh and Moscow but Siberians as well, mainly young people.

Many among the personnel had no previous experience of work at a place lacking well-established facilities, but the plant's staff proved to be unanimous, close-knit and hard-working. They quickly set about bringing the surviving workshops back into order, restoring the equipment, heating and lighting systems. It was in these conditions that the design staff led by A. S. Moskalyov set about completing the project of the RM-1 (SAM-29) rocket-propelled interceptor and building its full-size mock-up.

The ADP of the RM-1 interceptor was prepared, using the aerodynamic layout of the Strela light aircraft as a starting point (this was a tailless aircraft with low aspect ratio wings of ogival-delta planform on which Moskalyov had worked in the 1930s). The interceptor, which was expected to attain supersonic speeds around 1,300 km/h (808 mph), was to be powered by two RD-2M3V engines designed by L. S. Dooshkin. The wings had a modified RAG-38 airfoil section with a thickness-to-chord ratio of 8%. The project did not mention any specific armament, and in the document it was presented as an experimental unarmed rocket-propelled aircraft rather than a fighter, but its true mission was quite obvious. The machine's design performance is presented in the table on page 49.

In September 1945 the modified and completed project was submitted to NKAP – specifically, to the newly established Department for prototype jet aircraft; its leaders were Pyotr V. Dement'yev (chief) and N. A. Zhemchoozhin (deputy chief).

Here we have to deviate somewhat from our story and explain some of the 'political' circumstances that sealed the fate of the project. At that time the situation in NKAP was taking a rather favourable turn for Moskalyov. The point was that during the preceding period Moskalyov had had a fairly edgy relationship with Deputy People's Commissar of Aircraft Industry Aleksandr S. Yakovlev. At that time Yakovlev, according to some stories, had to some extent fallen from favour with Stalin, for whom he acted as a counsellor in aviation matters. The reason for this was allegedly Yakovlev's serious error in evaluating Germany's chances of creating jet-powered aircraft by the end of the war. In an answer to Stalin's question about the German capabilities in this respect Yakovlev, according to some sources, resolutely dismissed such a possibility as unrealistic. Yet, as is well known, German rocket-propelled and turbojet-powered aircraft did take part in the closing stages of the war. It is unknown how Yakovlev managed to save face before Stalin in this awkward situation, but, as mentioned above, a new Directorate dealing with jet aircraft was set up in the People's Commissariat of Aircraft Industry. Formally it was the charge of Deputy People's Commissar of Aircraft Industry Pyotr V. Dement'yev (piston-engined aircraft were left in Yakovlev's domain), but, due to Dement'yev's high workload, the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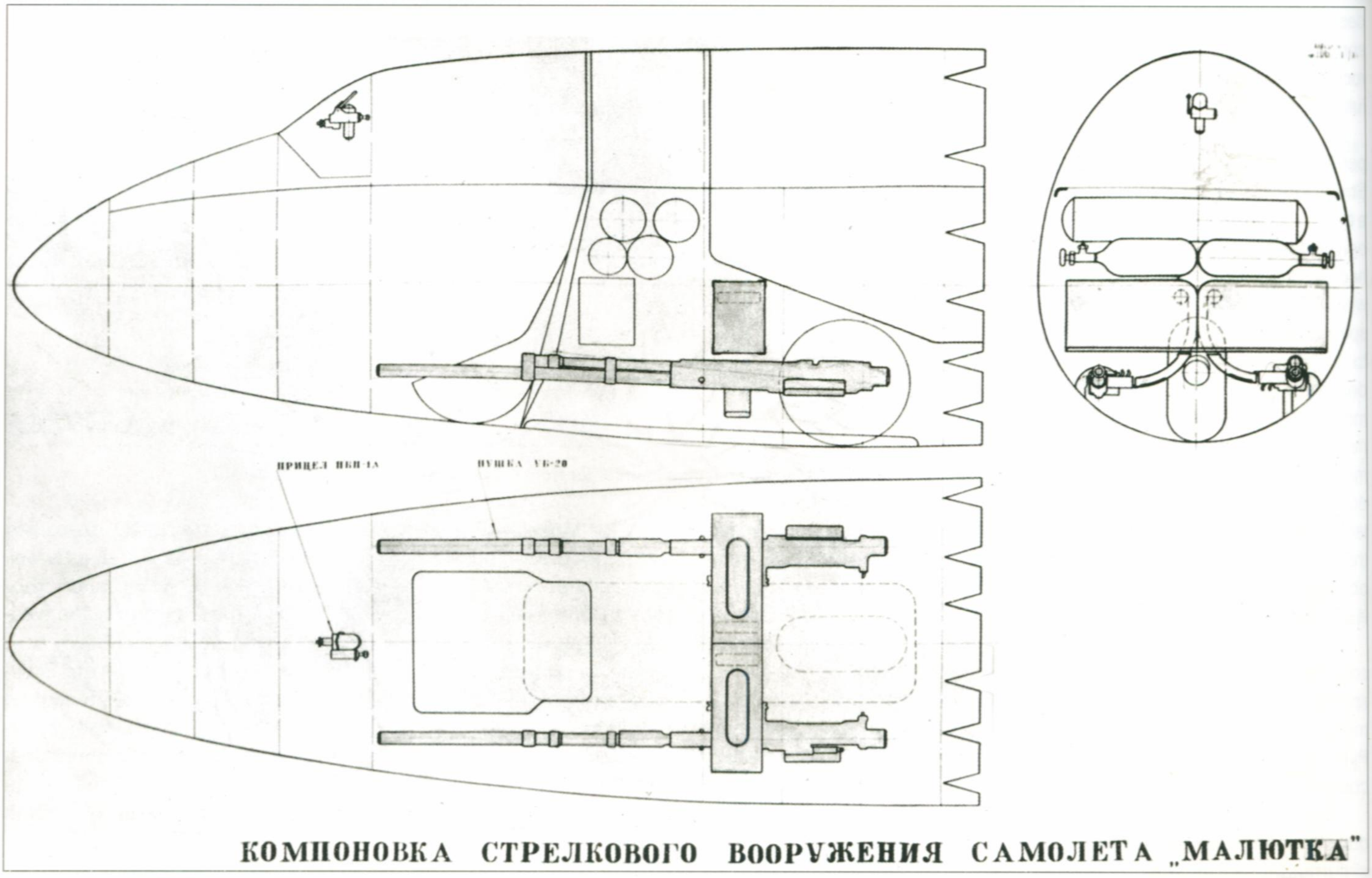
Above: These drawings show the Malyutka's landing gear design, including the position of the wheels in no-load, ground static and maximum oleo compression positions.

actual control of the new Directorate was exercised by N. N. Polikarpov's former deputy, the highly professional and experienced aircraft designer N. A. Zhemchoozhin who, as mentioned above, was appointed deputy chief. This 'distribution of portfolios' in NKAP might imbue Moskalyov with some hope for a positive assessment of his project.

Here is what the designer himself wrote about that period in his memoirs:

'It was to N. A. Zhemchoozhin […] that I made a full report on the RM-1 project, supplementing it with full information on the Strela aircraft.

First of all, it was clear that the layout adopted for a fighter patterned on the Strela was guaranteed against the troubles that had caused Bakhchivandzhi's fatal crash in the BI.

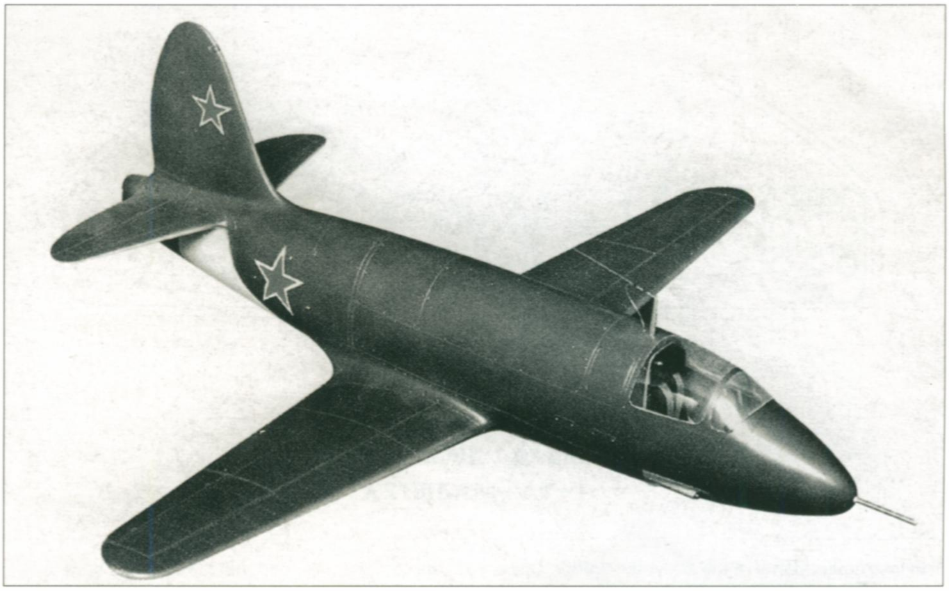


Another drawing from the Malyutka's project documents showing the fighter's armament. Note how the nosewheel stows between the breeches of the Berezin UB-20 cannons flanking the cockpit; the gunsight is a PKP-1A collimator sight.

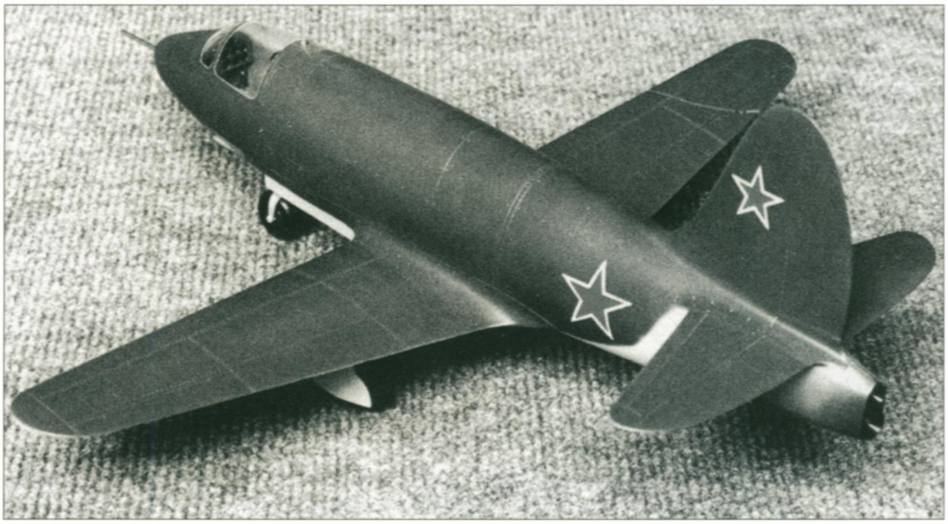
The fact that the Germans had made use of swept-back wings on their high-speed jet-powered aircraft gave reason, proceeding from both theory and practice, to expect positive qualities from the wings of the Strela in the area of shock stall and in supersonic flight.

The absence of transonic and supersonic wind tunnels made it imperative that a real hardware experiment be undertaken with the RM-1 aircraft. The expected good behaviour of the RM-1 at high flight speeds would make it possible to achieve a breakthrough in the development of aviation in comparison with achievements abroad…'

Indeed, after the project of the RM-1 had passed a preliminary study at TsAGI and received a positive conclusion, it was submitted for consideration to P. V. Dement'yev and then to People's Commissar A. I. Shakhoorin. The latter gave his support to the idea of building a prototype of the RM-1 and instructed his staff to prepare a draft Order calling for the construction of the aircraft in Leningrad. Thus, in the autumn of 1945 the aircraft was included into the draft plan for prototype aircraft construction for 1946.



Above and below: Another display model of the Malyutka showing a different canopy design (which was probably inaccurate). Note the vertically paired rocket motor nozzles.



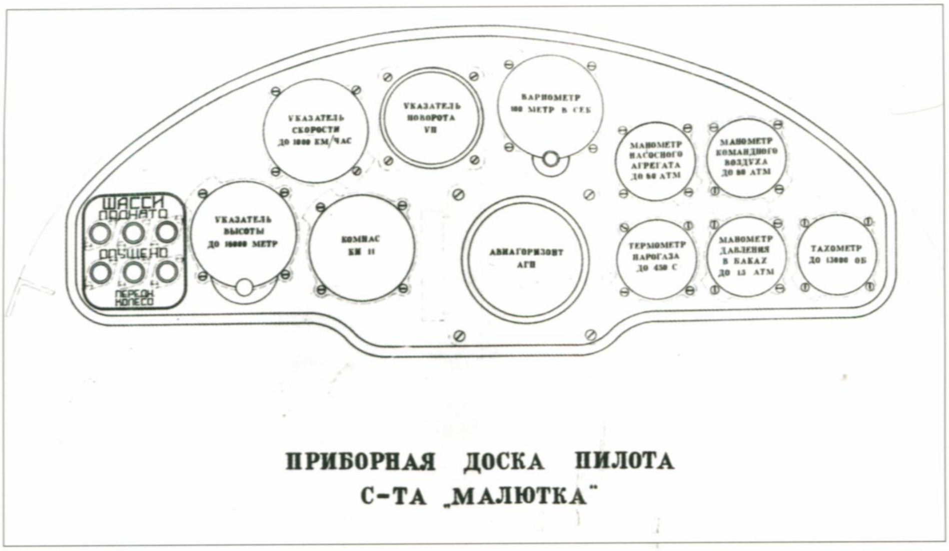
In early November 1945 the draft Order was ready and was properly initialled. Some delay occurred while the plant which was to manufacture the aircraft was selected. Plant No.273, where A. S. Moskalyov's design staff was based, was considered to have suffered too serious damage. Plant No.272 (formerly plant No.23) was in much better condition. Eventually, bearing in mind the importance attached to the RM-1 project, a decision was taken to transfer the staff of OKB-51 to plant No.272 and to ensure that the interceptor be manufactured there. All of this took time. Annual reports, plans and bureaucratic procedures with the handling of documents in NKAP – all this caused the signing of the Order to be delayed until December 1945. As Moskalyov himself recalled later, around 20th December he got the feeling that something had gone wrong in the NKAP machinery. Members of the staff were casting meaningful glances and talking in whispers. As it turned out, A. S. Yakovlev had reported to I. V. Stalin about some serious deficiencies in the work of the People's Commissariat of Aircraft Industry, presumably mentioning the fact that he, Yakovlev, was barred from the control of the 'jet technology Directorate', and possibly something else… Therefore, Stalin appointed a State Commission for investigating the activities of NKAP. The Commission was presided by Council of People's Commissars Chairman Gheorgiy M. Malenkov, with Yakovlev as his deputy.

Design Performance of the RM-1 Aircraft

Wing span	5.24 m (17 ft 2¼ in)
Wing area, m^2 (sq ft)	28.3 (304.6)
All-up weight, kg (lb)	5,490 (12,105)
Maximum speed, km/h (mph):	
at sea level	1,350 (839) (Mach 1.103)
at 5,000 m (16,400 ft)	1,330 (827) (Mach 1.155)
Landing speed, km/h (mph)	133 (83)
Time to altitude, minutes:	
to 5,000 m (16,400 ft)	2.74
to 10,000 m (32,800 ft)	4.4
Endurance, minutes	
at 5,000 m	27
at 10,000 m	24
Take-off run, m (ft)	860 (2,820)

By that time deputy chief of Directorate for jet aircraft N. A. Zhemchoozhin informed A. S. Moskalyov that the order on the construction of the RM-1 had been signed by People's Commissar A. I. Shakhoorin, but because of the Commission's work all current affairs had come to a standstill. He recommended that Moskalyov should go to Leningrad, celebrate the New Year of 1946 there and come back in early January for receiving the signed papers. Moskalyov followed this advice. However, when he came to Moscow in early 1946, he was confronted with a complete 'debacle' of NKAP. People's Commissar Shakhoorin had been relieved of his duties and persecuted. At the same time all of Shakhoorin's deputies and nearly all heads of NKAP's directorates were fired from their posts; only P. V. Dement'yev had retained his post of 'third deputy'. Rumours had it that Stalin had forbidden to 'touch' Dement'yev because of the latter's great services to the country during the war.

The Order calling for the construction of the RM-1 was cancelled by A. S. Yakovlev. The aircraft's designers were asked to submit still more weighty arguments in favour of the project. The downhearted Moskalyov sent the project of the RM-1 interceptor for consideration to the Leningrad Red Banner Military Air Academy named after Aleksandr F.


УКАЗАТЕЛЬ СКОРОСТИ ДО 1000 КМ/ЧАС
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МАНОМЕТР НАСОСНОГО АГРЕГАТА ДО 60 АТМ
МАНОМЕТР КОМАНДНОГО ВОЗДУХА ДО 60 АТМ
ШАССИ ПОДНЯТО
ОПУЩЕНО
ПЕРЕДН КОЛЕСО
УКАЗАТЕЛЬ ВЫСОТЫ ДО 10000 МЕТР
КОМПАС КИ 11
АВИАГОРИЗОНТ АГП
ТЕРМОМЕТР ПАРОГАЗА ДО 450 С
МАНОМЕТР ДАВЛЕНИЯ В БАКАХ ДО 15 АТМ
ТАХОМЕТР ДО 13000 ОБ
ПРИБОРНАЯ ДОСКА ПИЛОТА
С-ТА „МАЛЮТКА"

The instrument panel of the Malyutka fighter. Upper row, left to right: airspeed indicator, turn & bank indicator, vertical speed indicator; lower row: landing gear position lights, altimeter, compass, artificial horizon, steam/gas temperature gauge, fuel/oxidiser tank pressurisation gauge and tachometer.

Mozhaiskiy (LKVVIA – *Lenin**grahd**skaya krasnozna**myon**naya vo**yen**no-voz**doosh**naya inzhe**ner**naya aka**dem**iya*). The conclusion endorsed on 2nd March 1946 by General Ponomaryov, the Academy's Chief, and cited in full below, was styled in literally rapturous terms:

Conclusion on the advanced development project of the 'RM' jet aircraft designed by engineer Moskalyov

Having heard the report of Chief Designer A. S. Moskalyov and having considered the advanced development project of the 'RM' aircraft featuring the low-aspect-ratio flying wing layout and powered by the RD-2M3V liquid-fuel rocket motor designed by Dooshkin, we have come to the following conclusion.

1. The present project successfully solves the problems of flight both at conventional speeds and at speeds approaching the speed of sound.

2. The solution of these issues for conventional speeds (up to Mach 1) is based on the factual data obtained in wind tunnel tests and in the course of flight testing of the Strela experimental aircraft (built in 1937), the present project being an improved version of the layout of this aircraft.

3. This layout is of exceptional interest from the point of view of the requirements posed by high-speed aerodynamics.

The layout in question has the following advantages over the layouts that have been known to us so far:

a) The possibility to use relatively thin (C=8%) airfoil sections while retaining sufficient rigidity and vibration strength of the structure, which makes it possible to postpone the onset of the shock stall mode and to obtain the value of Mcrit (critical Mach number – *Auth.*) *close to Mach 1;*

b) Losses caused by interference drag are minimised;

c) The aircraft's performance is relatively little affected by changes of airfoil section (owing to the very low aspect ratio of 2); this makes it possible to use experimental super high-speed airfoils at low speeds (take-off and landing speeds);

d) The use of super-high-speed airfoils makes it possible to surmount the maximum drag with the help of usual means of flight acceleration (for example, take-off rocket boosters) and to attain supersonic speeds.

4. Stability and controllability issues, which have been solved with regard to conventional speeds on the Strela aircraft, are being studied experimentally in wind tunnel tests and in flight with regard to speeds equal to the speed of sound and in excess of it.

5. The aircraft's performance figures quoted in the project do not give reason for any particular doubts.

On the basis of the above it appears that the proposed jet aircraft is an extremely interesting object for scientific research and experimental work.

Implementation of this project must become an urgent task of the prototype aircraft construction.

Chiefs and leading collaborators of the Chair of Aircraft Construction fully support the initiative of Chief Designer A. S. Moskalyov concerning the setting up of a scientific research centre for prototype aircraft construction in Leningrad.

The involvement of the Academy's scientific potential and means in the development and construction of this aircraft will contribute to enhanced development of the Academy's scientific and experimental facilities.

(signed) Chief of NIO (Scientific Research Section – *Auth.*) *Engineer-Major Marusenko;*

Engineer-Colonel, Professor Rostovtsev;

Engineer-Lieutenant-Colonel, Professor, Doctor of Technical Sciences Rozanov;

Engineer-Lieutenant-Colonel, Professor, Doctor of Technical Sciences Mel'nikov.

In the meantime, Mikhail V. Khrunichev was appointed Minister of Aircraft Industry (in March 1946 all People's Commissariats became Ministries, and the Council of People's Commissars (SNK) became the Council of Ministers). According to comments from long-time NKAP employees, Khrunichev was a specialist in logistics. Aleksandr S. Yakovlev was appointed First Deputy Minister; at the same time he directly headed the now joint Chief Directorate for Prototype Construction and the personnel department (!).

Aleksandr S. Moskalyov was convinced that Yakovlev's decision to exclude the RM-1 rocket-propelled interceptor from the prototype construction plan was erroneous. Accordingly, in a letter addressed to Chairman of the State Planning Committee (Gosplan) Voznesenskiy he stressed that this decision was ill-founded.

Yakovlev had to substantiate his decision. Making use of the control he exercised over TsAGI, Yakovlev appointed a new commission to review the RM-1 project. The commission included prominent figures in the field of aviation: A. V. Chesapov, I. V. Ostoslavskiy, V. I. Polikovskiy, P. Ya. Zalesskiy, N. I. Petrov, V. N. Alekseyev, M. G. Benderskiy, N. Z. Matyuk *et al*. In July 1946 at its meetings in the Ministry of Aircraft Industry (MAP – *Mini**ster**stvo aviatsi**on**noy pro**mysh**lennosti*) this commission examined the project but, being unwilling to assume the unwelcome responsibility for an aircraft of such a 'revolutionary' layout, it gave a very ambiguous conclusion, making a vague reference to 'difficulties' which TsAGI 'was going to' try and surmount. Among other things, Protocol No.63 dated 20th July 1946 stated:

'1. The idea of using low-aspect-ratio swept-back wings on high-speed aircraft merits its attention. The implementation of this idea involves a whole range of difficulties which so far remain unresolved:

a) aircraft similar to the Strela are prone to oscillations around the longitudinal axis, no measures have yet been evolved to counteract this phenomenon;

b) the low wing aspect ratio hampers the aircraft's longitudinal control during landing, a solution to this problem […] has not been found either;

c) the controls of this aircraft lose their efficiency at high Mach numbers, which makes this aircraft dangerous at high speeds.

2. Studies on the subject 'Aircraft with of low aspect ratio wings' have lately been conducted at TsAGI.

3. Construction of an aircraft designed as a flying wing of low aspect ratio and intended for flights at high speeds cannot be undertaken before TsAGI has found solutions to the above-mentioned questions associated with it.'

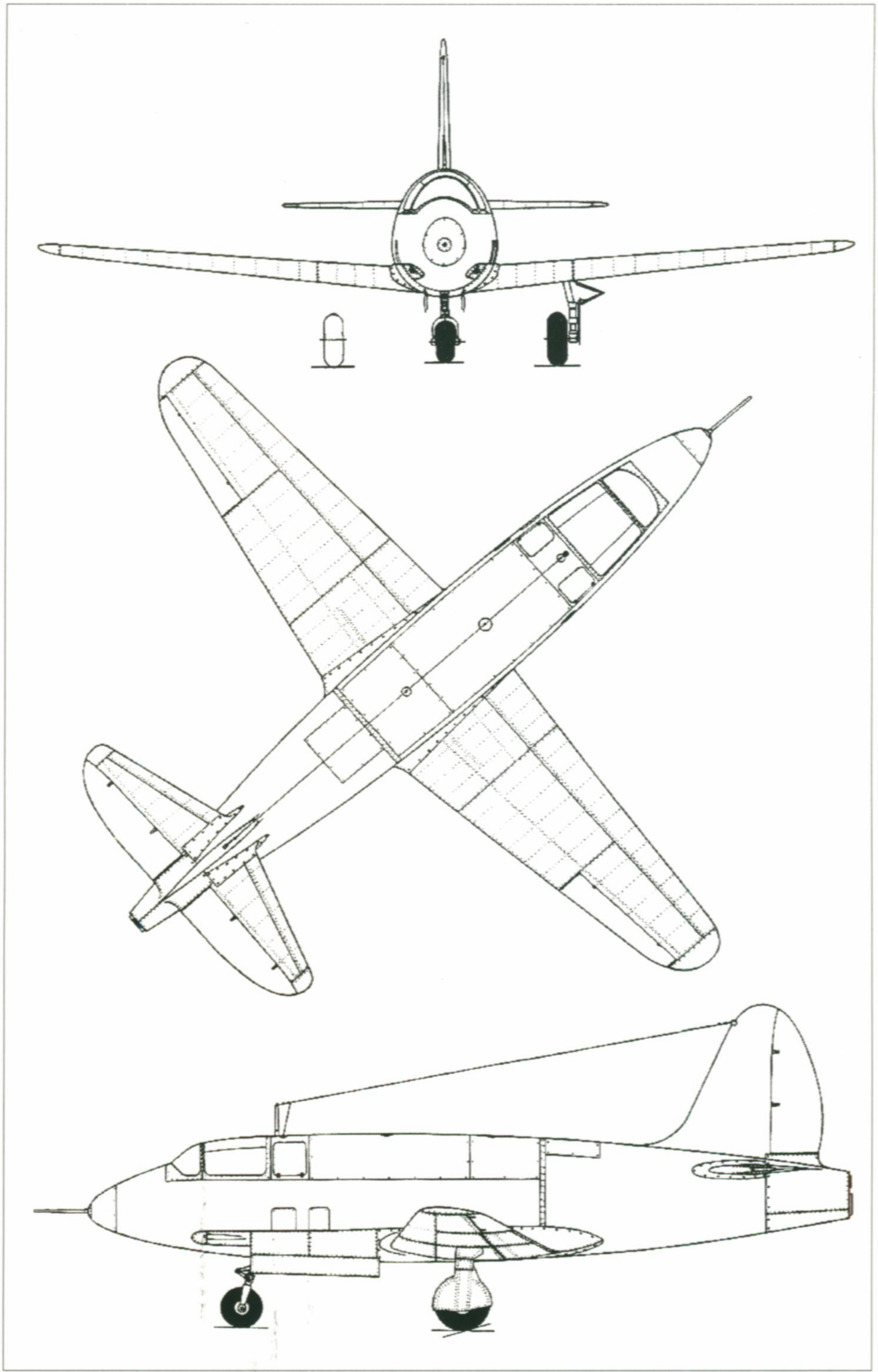
The protocol clearly shows the biased attitude of the new commission to the project, which manifested itself in the wilfully invented, allegedly existing difficulties. Here are just a few facts.

Firstly, the Report on the testing of the Strela aircraft makes no mention of poor longitudinal control. On the contrary, both test pilots involved (N. S. Rybko and A. N. Gusarov) expressly stated that the elevator authority was quite sufficient for a landing and that the handling was as uncomplicated as that of the Polikarpov Po-2 primary trainer biplane. The possibility of loss of control at high Mach numbers was no more than a supposition which was not substantiated in any way. Secondly, TsAGI started studying the subject of aircraft with low-aspect-ratio wings only in connection with the construction and testing of the Strela aircraft intended for low flight speeds. With regard to transonic and supersonic flights TsAGI had no possibility to check the aerodynamics of a delta-wing aircraft – simply because supersonic wind tunnels were unavailable. Thus, Protocol No.63 was far-fetched from beginning to end and ran contrary to the first (preliminary) conclusion by TsAGI and the subsequent conclusion issued by LKVVIA. The absence of supersonic wind tunnels at that time turned any talk about TsAGI researching the Strela layout at supersonic flight speeds into nonsense. As is well known, it was not before the early 1950s that such wind tunnels came into being in the USA, and still later in the USSR. In fact, TsAGI had no intention at all to conduct any work on investigating the Strela's layout.

This was not the first case when the leaders of the Soviet aircraft industry in general, and of the Chief Directorate on Prototype Aircraft Construction in particular, were reluctant to admit their backwardness as regards aerodynamic research and rejected promising projects, despite the support that many of them received from the Air Force Command.

After that Aleksandr S. Moskalyov sent a report to Commander-in Chief of the Air Force Air Marshal K. A. Vershinin, asking him for support, but the latter was obviously unwilling to deal with the matter and gave an ambiguous reply.

Shortly thereafter, in July 1946, MAP issued an order stipulating that an aircraft instrument factory from Kazan' should move to the premises of plant No.273; as for plant No.272, the entire personnel of plant No.499 was transferred to its premises. Deprived both of his design team and his production facility, A. S. Moskalyov was transferred to MAP's Personnel Department. This meant the termination of all work on the RM-1 interceptor.



A three-view drawing of the 'aircraft Sh' (Malyutka) interceptor.

'R' and R-114 Supersonic Interceptors (Projects)

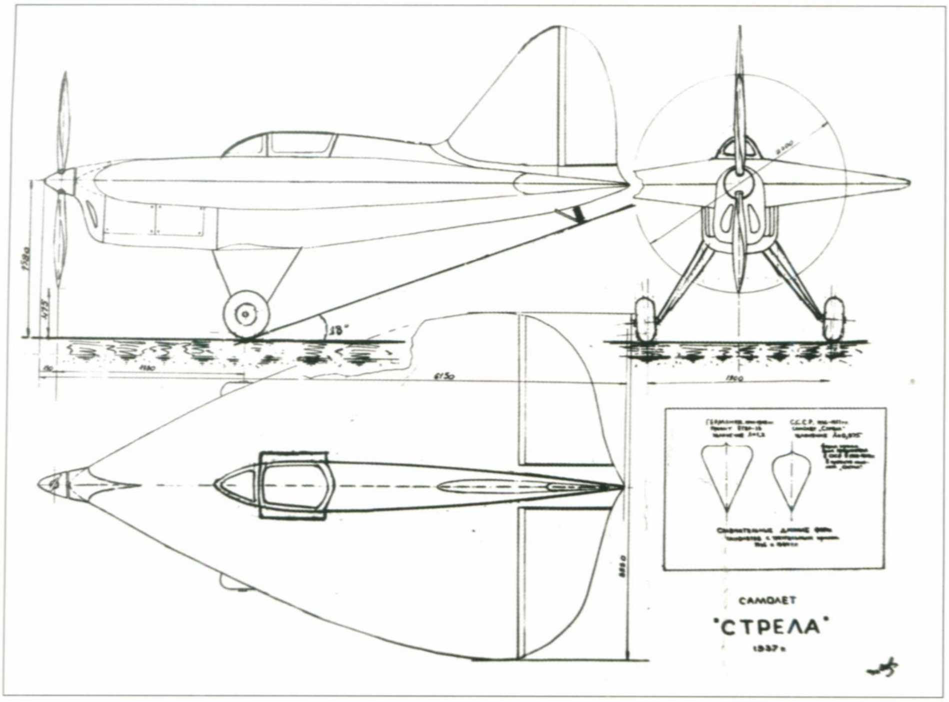
During the war years the possibility of creating a high-speed rocket-propelled interceptor was also studied in Omsk by Roberto L. Bartini, an Italian designer who had worked for many years in the USSR by then. He came to Omsk together with TsKB-29 – a special design bureau set up under the auspices of NKAP and evacuated to that city after the outbreak of the war. The infamous People's Commissar of Internal Affairs Lavrentiy P. Beriya personally tasked Bartini with the development of this aircraft. Bartini prepared two projects; the first of them, developed as early as 1941, was known as aircraft 'R'. It was a supersonic single-seat fighter featuring a flying-wing layout. It had wings of low aspect ratio with strong leading-edge sweep that varied along the span. The aircraft featured twin vertical tails mounted at the wingtips (!) and was to have a composite powerplant combining a liquid-fuel rocket motor and a ramjet. The second project, which bore the designation R-114, was a point-defence interceptor. It was powered by four RD-1 rocket motors developed by V. P. Glushko, each of them having a thrust of 300 kgp (661 lbst). Its wings had 33º leading-edge sweep and were provided with boundary layer control for the purpose of improving the lift/drag ratio. The R-114 was to attain a speed corresponding to Mach 2 – something unheard of in 1942! However, during the harsh war years the construction of such an aircraft was beyond any realistic possibility. Officially the rejection of the project was motivated by insufficient research data on the properties of swept wings. In the autumn of 1943 the group led by Bartini was reorganised and merged into other design subdivisions.

Interestingly, Bartini made no secret of the fact that his idea of creating rocket-powered interceptors with delta wings was prompted by A. S. Moskalyov's Strela.

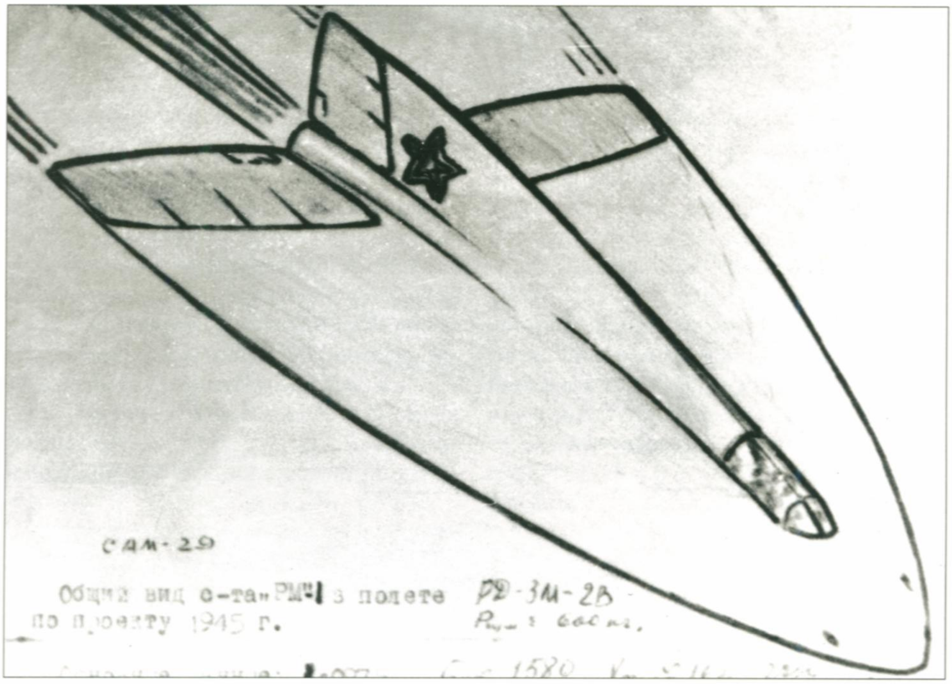
After the crash of the BI aircraft in which test pilot G. Bakhchivandzhi lost his life, it became clear even to those with little knowledge of aerodynamics that the existing aircraft layouts were ill suited for high-speed flight. Aircraft featuring a subsonic layout are prone to entering an uncontrollable dive at high speeds for two reasons: the rearward shift of the wings' aerodynamic focus and the abrupt reduction of the wing downwash. This leads to a pitch-down force which is virtually impossible to counteract. Conversely, aircraft featuring the swept-back flying wing layout experience a shock stall of low intensity, and the shift of the pressure centre is negligible. In certain low aspect ratio wing shapes (double-delta wings or wings with a cranked leading edge) the aerodynamic focus virtually does not shift as the aircraft goes supersonic.

However, the nation was fighting a war, which left little room for experiments. At present it is difficult to judge what the leaders of the Soviet aircraft industry ought to have done in this or that situation. All the more so, if one bears in mind the devastating reprisals which decimated the nation's engineering staff.

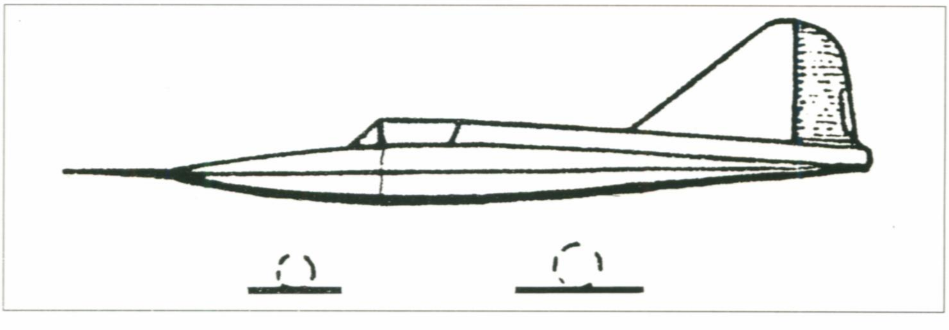
Yet, it may well be noted that in the Soviet Union, irrespective of the research conducted in other countries (in particular, in Germany), theoretical research and development of prospective high-speed swept-wing fighters reached a sufficiently high level. Eventually this allowed the Soviet Union to be on a par with the leading western countries in the field of jet aircraft by the early 1950s.



Above: A three-view drawing of the pre-war SAM-9 Strela proof-of-concept aircraft which triggered the development of the RM-1 (SAM-29) interceptor.



Above: A sketch of the futuristic RM-1 (SAM-29) made by Aleksandr Moskalyov; the machine followed the Strela's layout. Note the very large elevons and the vertical tail blending into the fuselage spine.



A side view of a very different (and probably earlier) project version of the RM-1.

Chapter 4

Making Use of German Experience

It is well known that when the Second World War had been won, the Soviet Union, like the other countries of the anti-Hitler coalition, came into possession of a large amount of German scientific and technical information in the field of military aviation obtained as war booty. *Ad hoc* commissions were sent to Germany to investigate these matters; the results of their work showed that Germany had advanced appreciably farther in the field of jet propulsion than Soviet designers had surmised, and had by far outstripped not only the USSR but the other superpowers as well. A report on this matter prepared for the Soviet leaders stated:

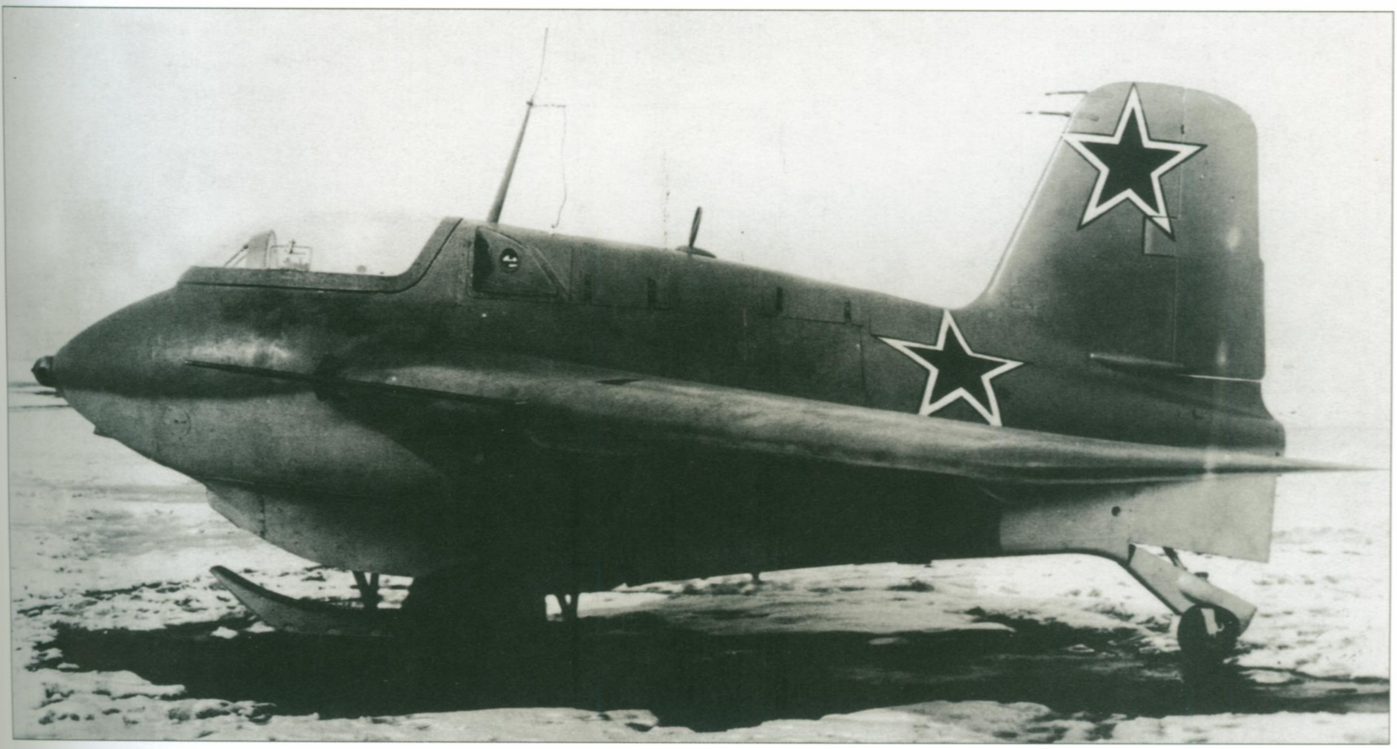
'In recent years the development of jet-propelled aircraft in Germany had acquired a wide scope. Examples of German jet aviation hardware captured by Soviet troops and now available in the USSR – jet aircraft (fighters, attack aircraft, bombers), turbojet engines for aircraft, liquid-fuel rocket motors, radio-guided and unguided rocket projectiles (long-range [attack] missiles and air defence missiles), winged missiles (cruise missiles – Auth.) *and radio-controlled gliding bombs guided from an aircraft – show that introduction of jet hardware in the Air Force, Navy and artillery troops was conducted in Germany on a large scale, the Germans having achieved a major success in this field.'*

In the summer of 1945 an interdepartmental Commission on Jet Technology was set up under the auspices of the Special Committee subordinated to the State Defence Committee. The Commission was to conduct a comprehensive study of the German achievements in jet propulsion technology with a view to making use of them in the USSR. The Commission comprised the leaders of the People's Commissariats of aircraft industry, munitions, electrical engineering, armaments, shipbuilding, chemical industry – Aleksey I. Shakhoorin (chairman), B. L. Vannikov, N. N. Voronov, A. I. Berg, Dmitriy F. Ustinov, N. D. Yakovlev, A. K. Repin, I. G. Kabanov, M. G. Pervookhin and L. M. Gaidukov.

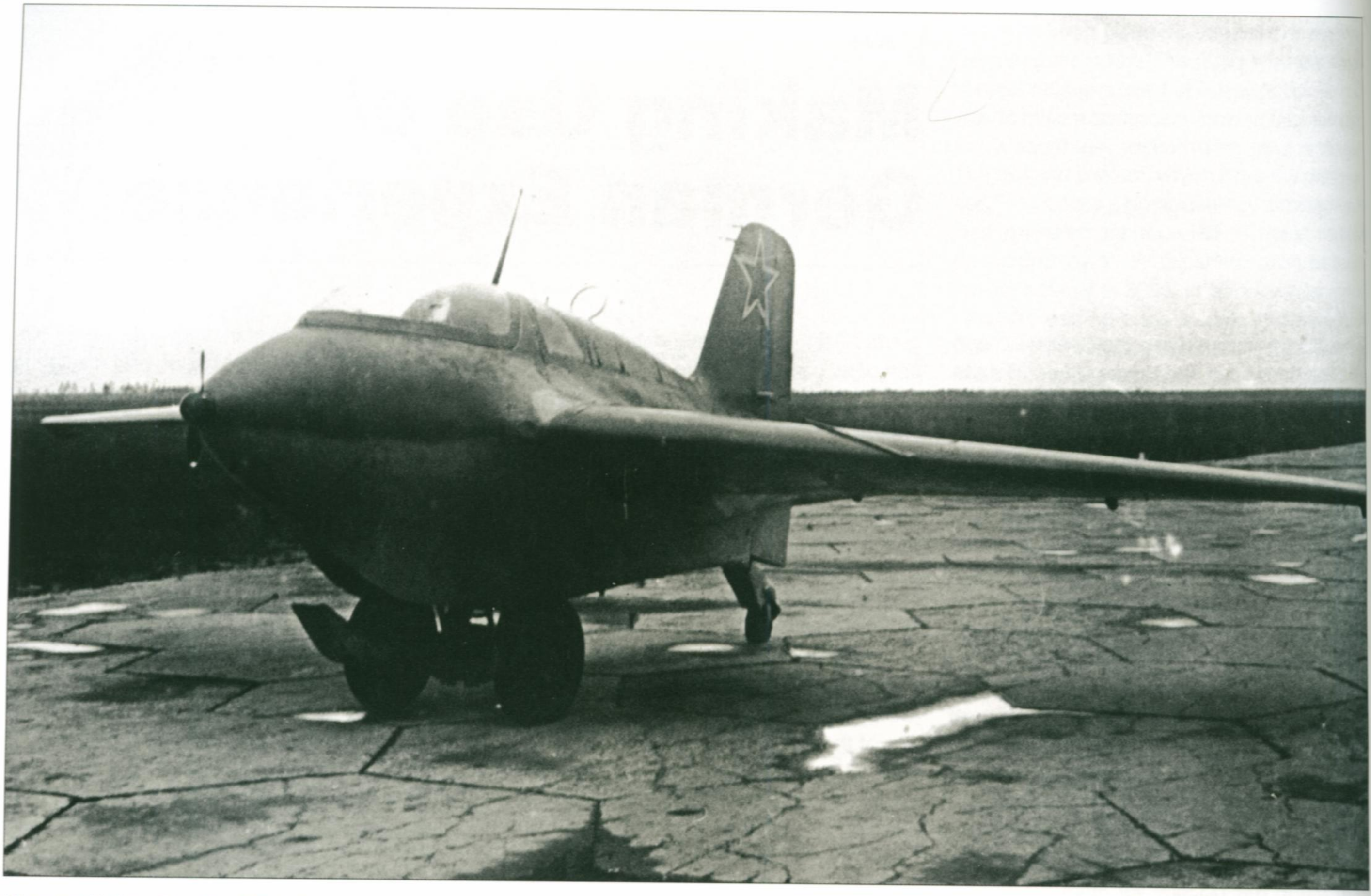
The recommendations issued by the Commission served as a basis for preparing a set of measures. Cited below is an excerpt from a resolution adopted by the State Defence Committee in 1945 and called 'On measures for the examination and mastering of German jet technology':

'The People's Commissariat of Aircraft Industry – Comrades Shakhoorin and Dement'yev, the chiefs of institutes, the chief designers and the directors of factories shall conduct the following work for the purpose of studying and mastering the German jet technology – turbojet engines, liquid-fuel rocket motors for aircraft, jet aircraft and winged missiles:

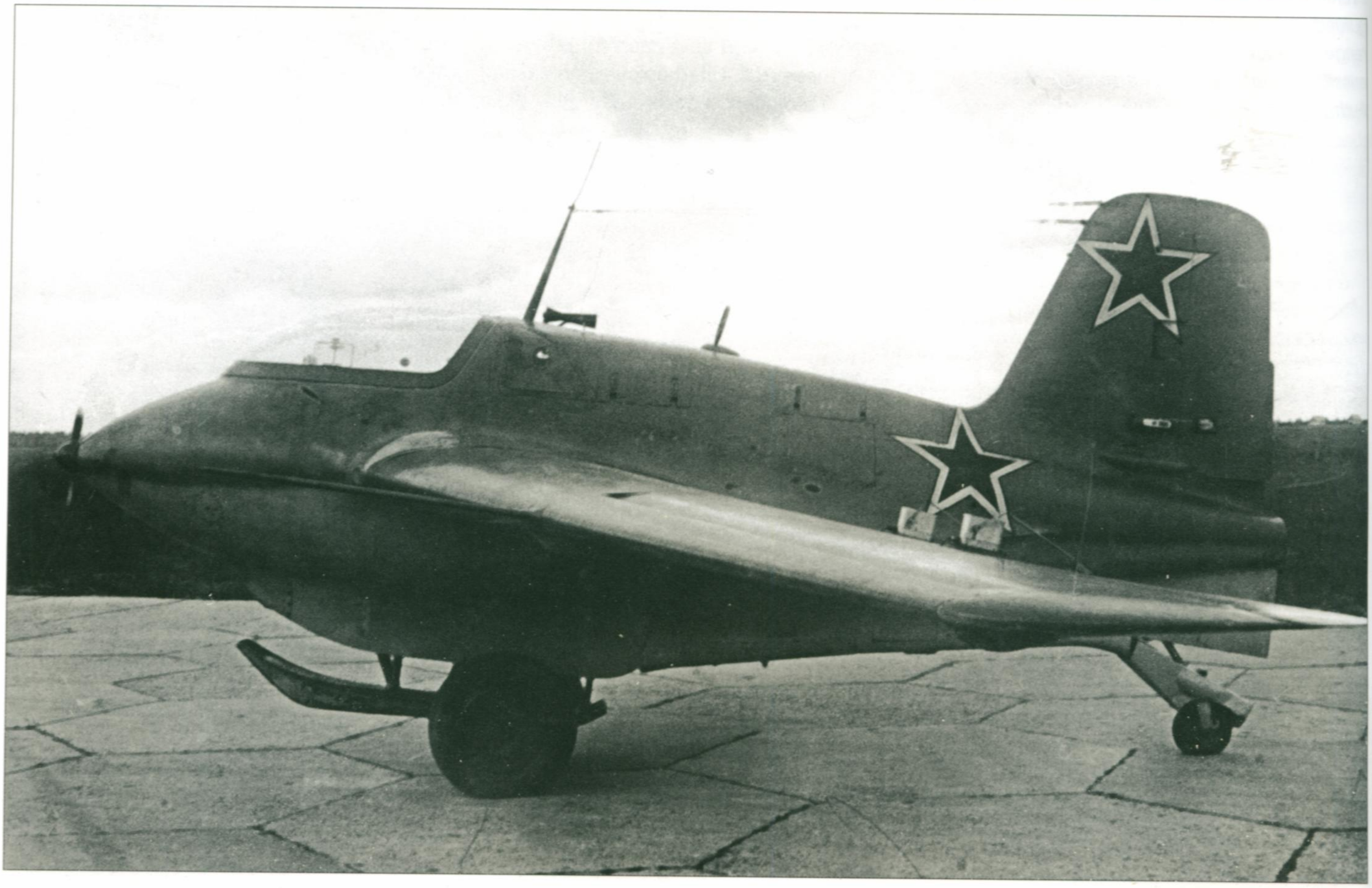
a) Chief of NKAP's NII-1 Comrade Bibikov and deputy chief Comrade Bolkhovitinov are to ensure the examination and mastering of German Walter and BMW liquid-fuel rocket motors, as well as of the engines intended for use as aircraft take-off boosters; the examination of fuels and oxidisers used by the Germans in liquid-fuel rocket motors, examination of the German Messerschmitt 163 jet fighter powered by the Walter liquid-fuel rocket motor, the examination of all scientific reports and materials of German research organisations and design bureaux in the field of liquid-fuel rocket motors and jet aircraft powered by liquid-fuel rocket motors...'

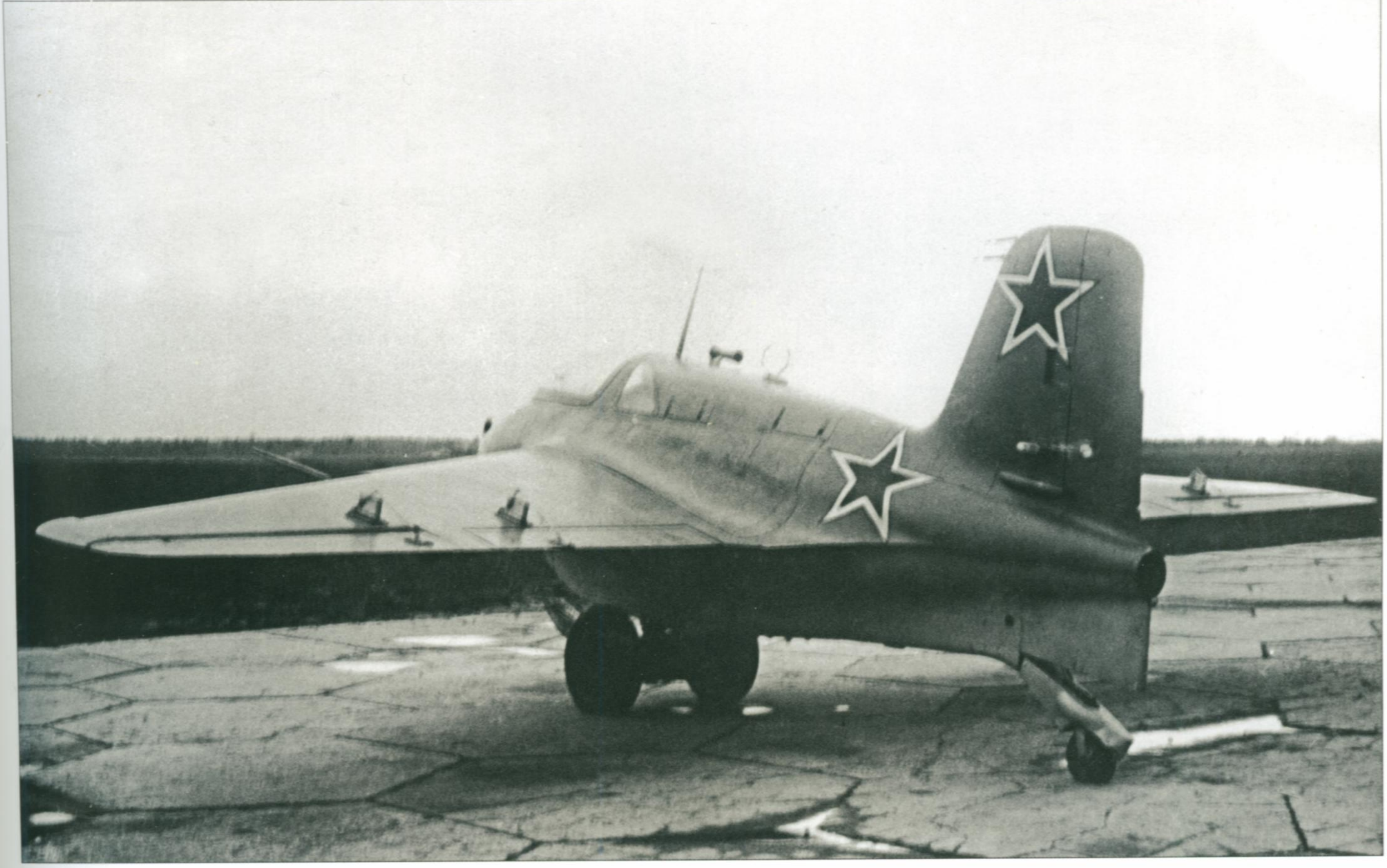


A captured Messerschmitt Me 163B Komet interceptor in Soviet insignia undergoing tests at GK NII VVS. Here the aircraft is still in 'as-was' condition (with no test equipment).

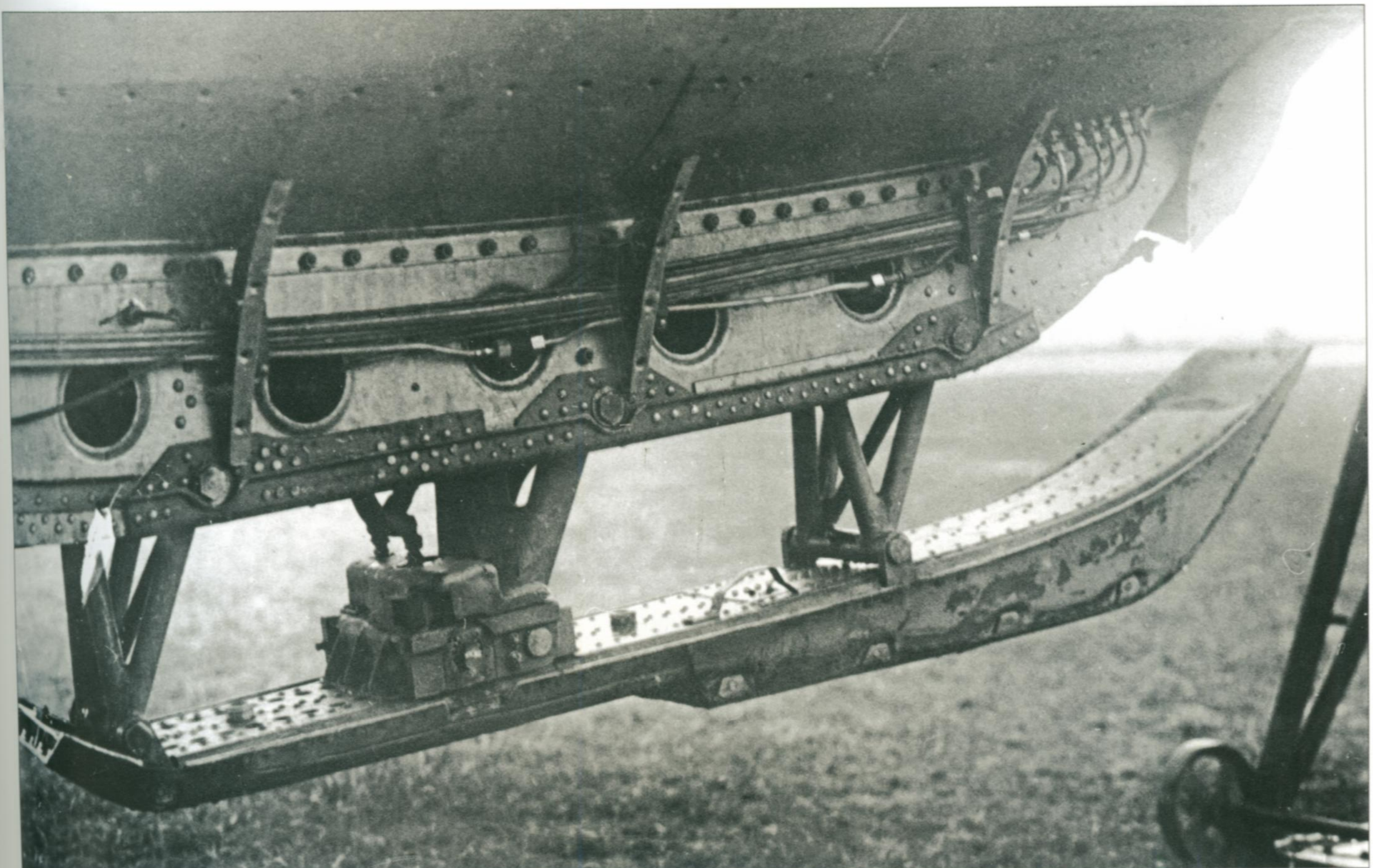


Above and below: The Me 163B sitting on its take-off dolly on the distinctive hexagonal slabs of the GK NII VVS apron at Chkalovskaya AB. The upper photo shows the loop aerial of the direction finder aft of the cockpit and the propeller-like vane on the nose driving the generator. Note the added dorsal Venturi tube.

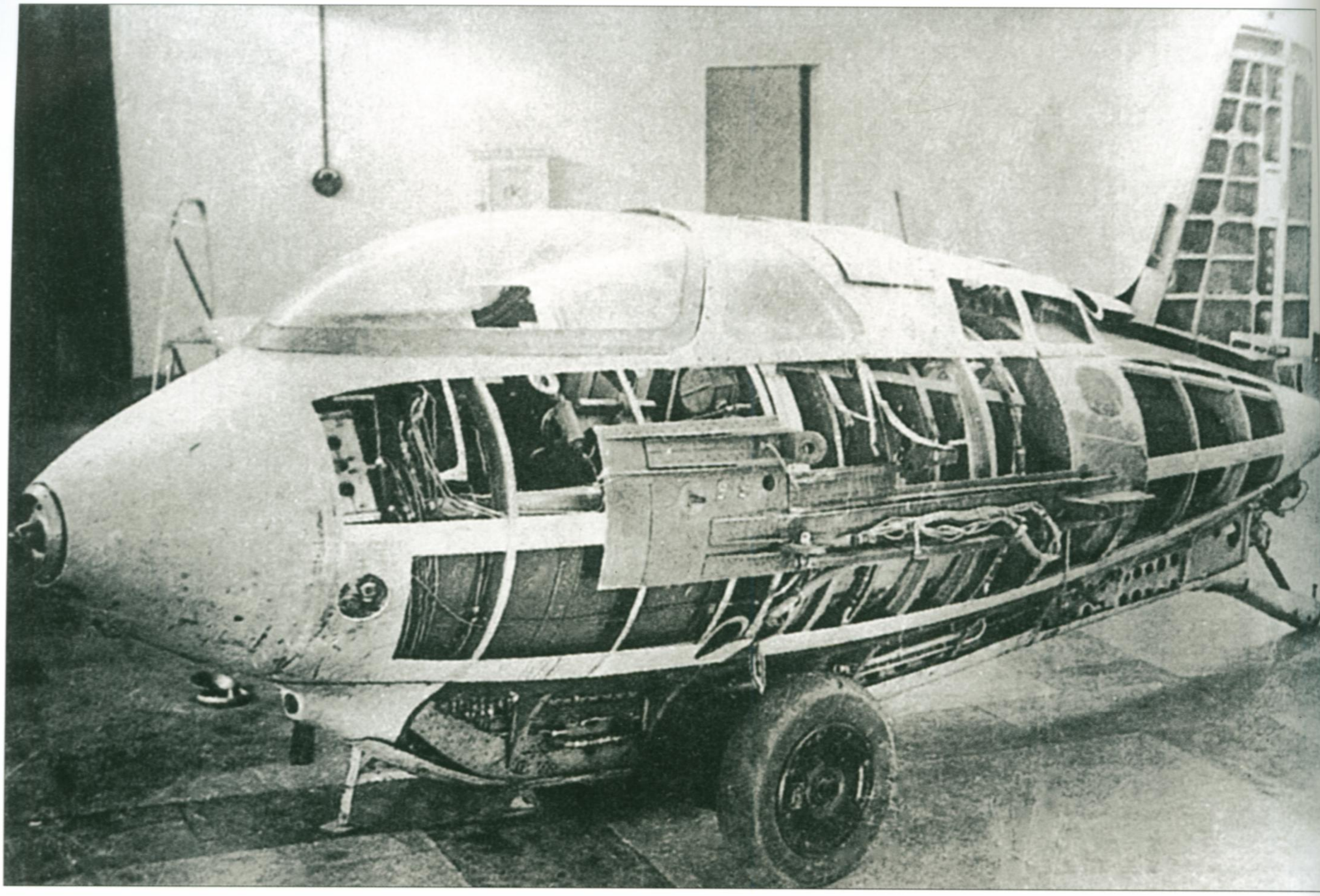




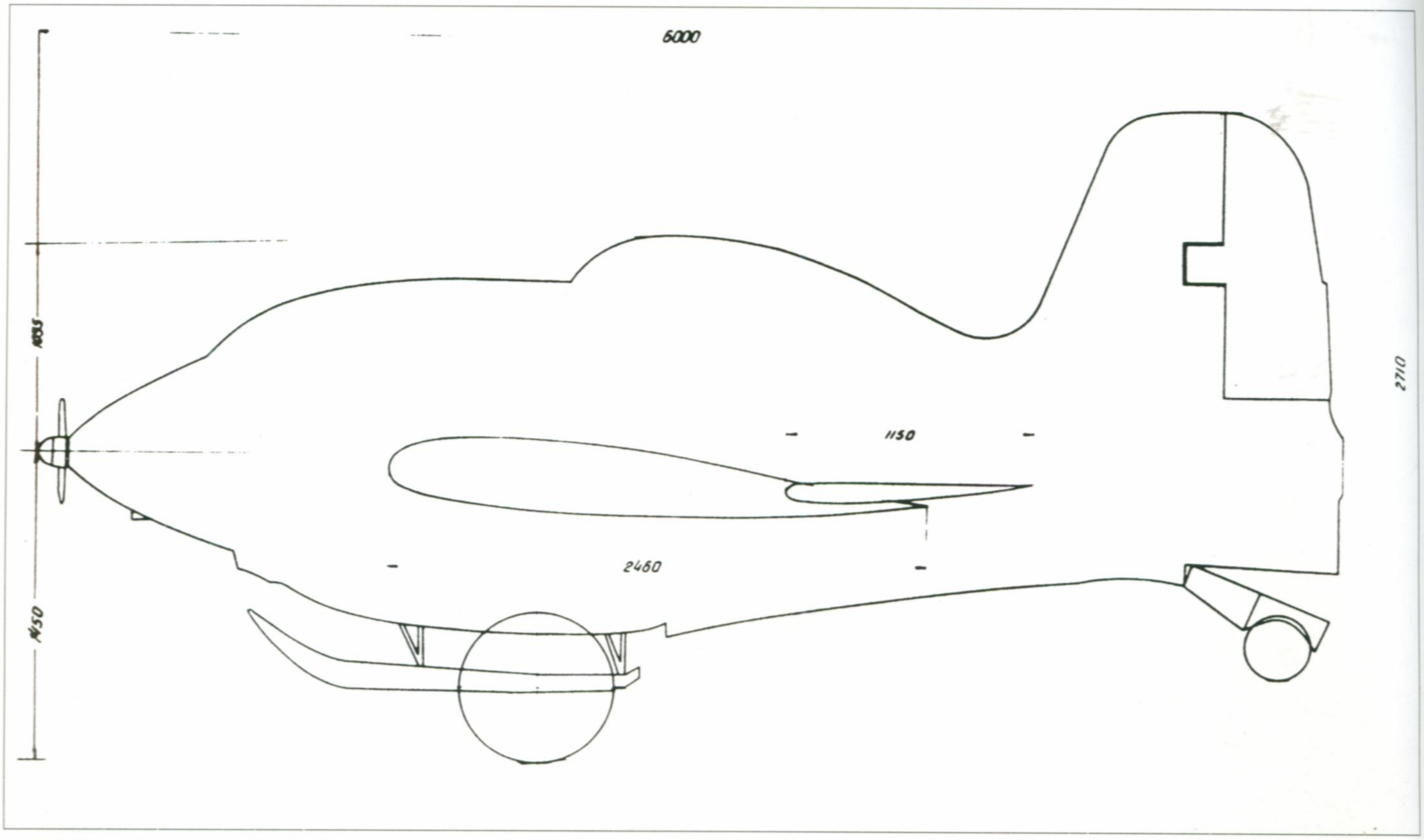
Above: Typically of NII VVS, faired deflection angle sensors forming part of the test equipment were fitted to the Me 163B's control surfaces during the trials.



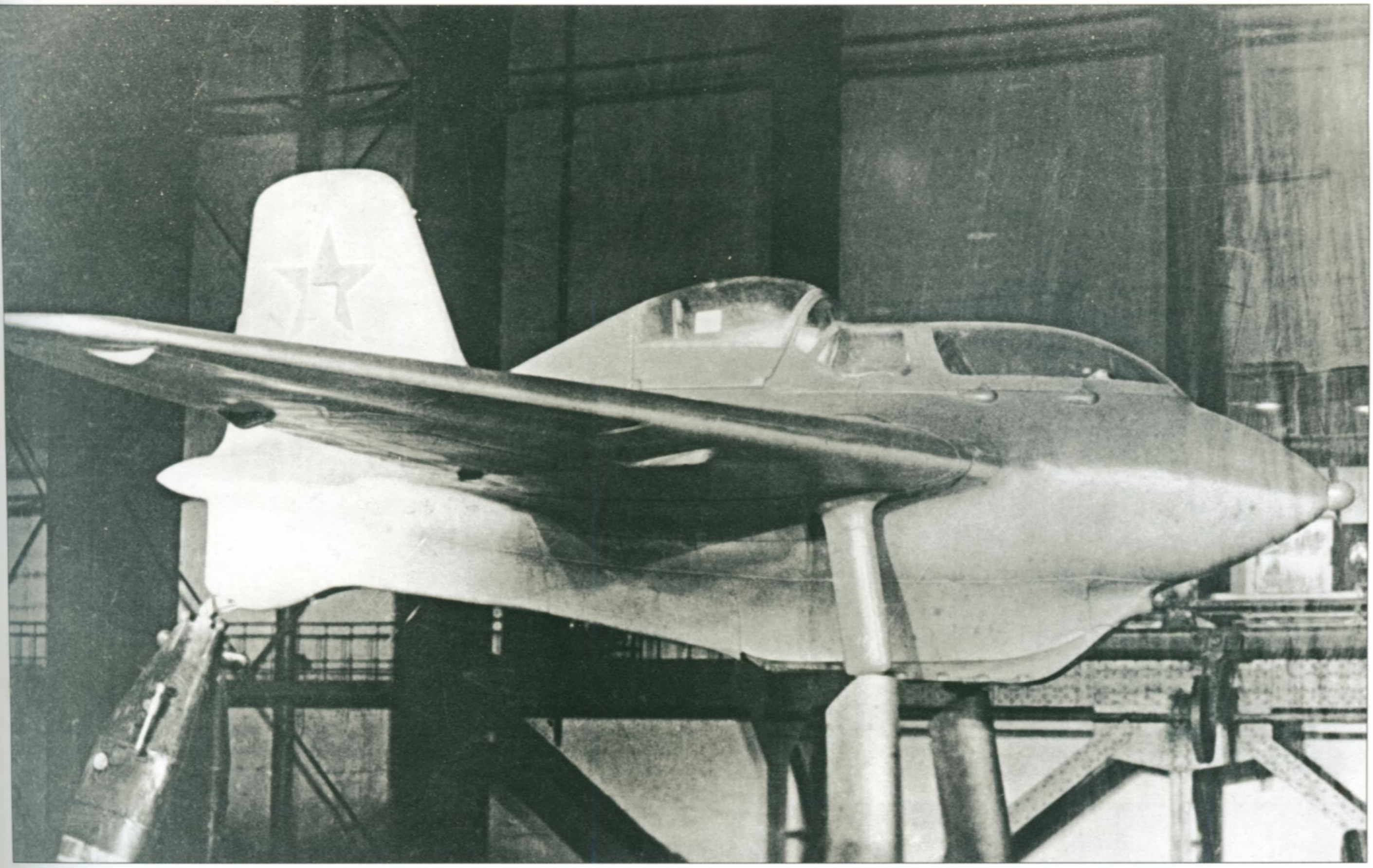
Close-up of the Me 163's extended main landing skid with the dolly detached.



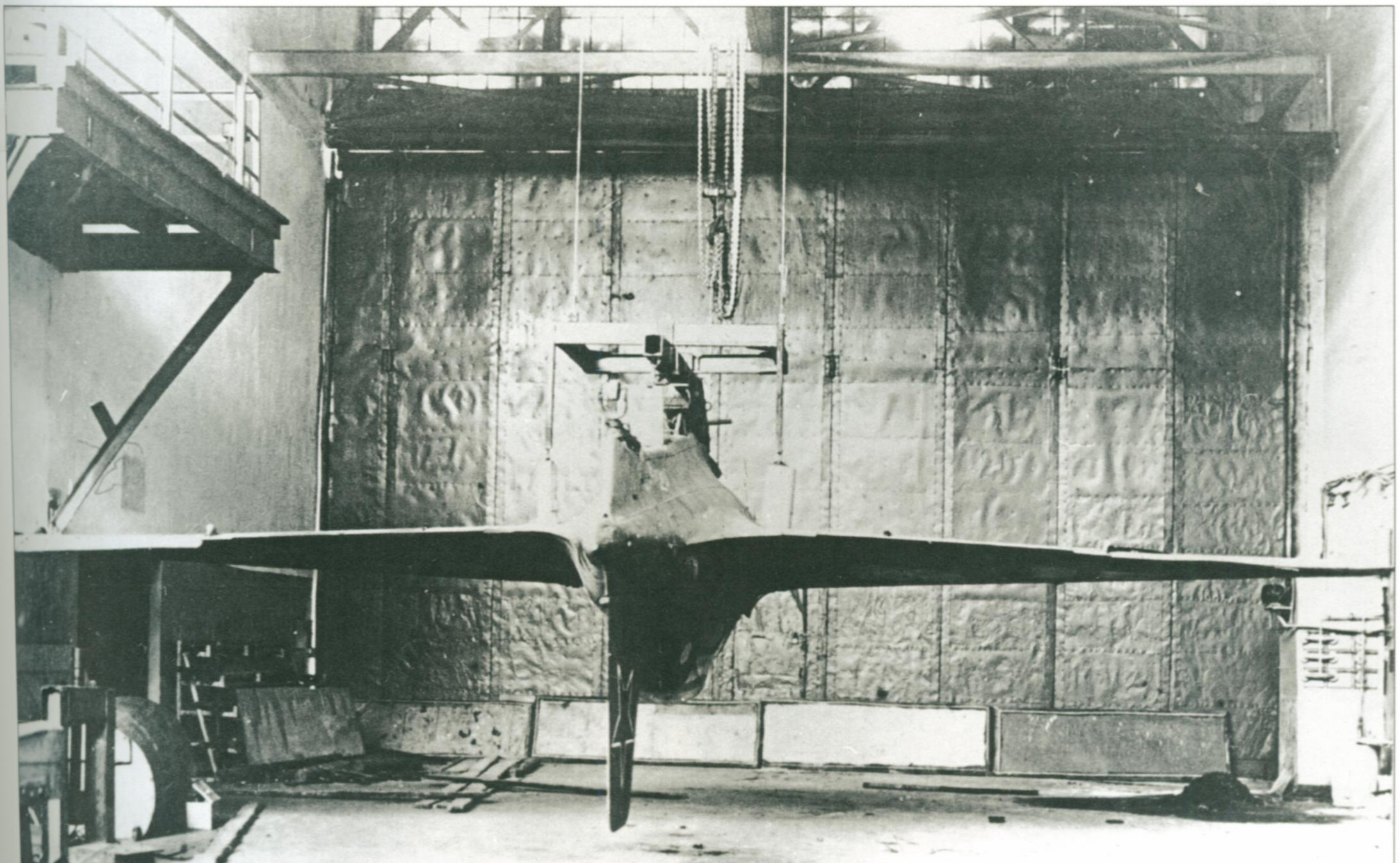
Above: This Me 163B ended up at TsAGI's Bureau of New Technologies (BNT) as a cutaway instructional airframe. Note that the main skid is retracted here.



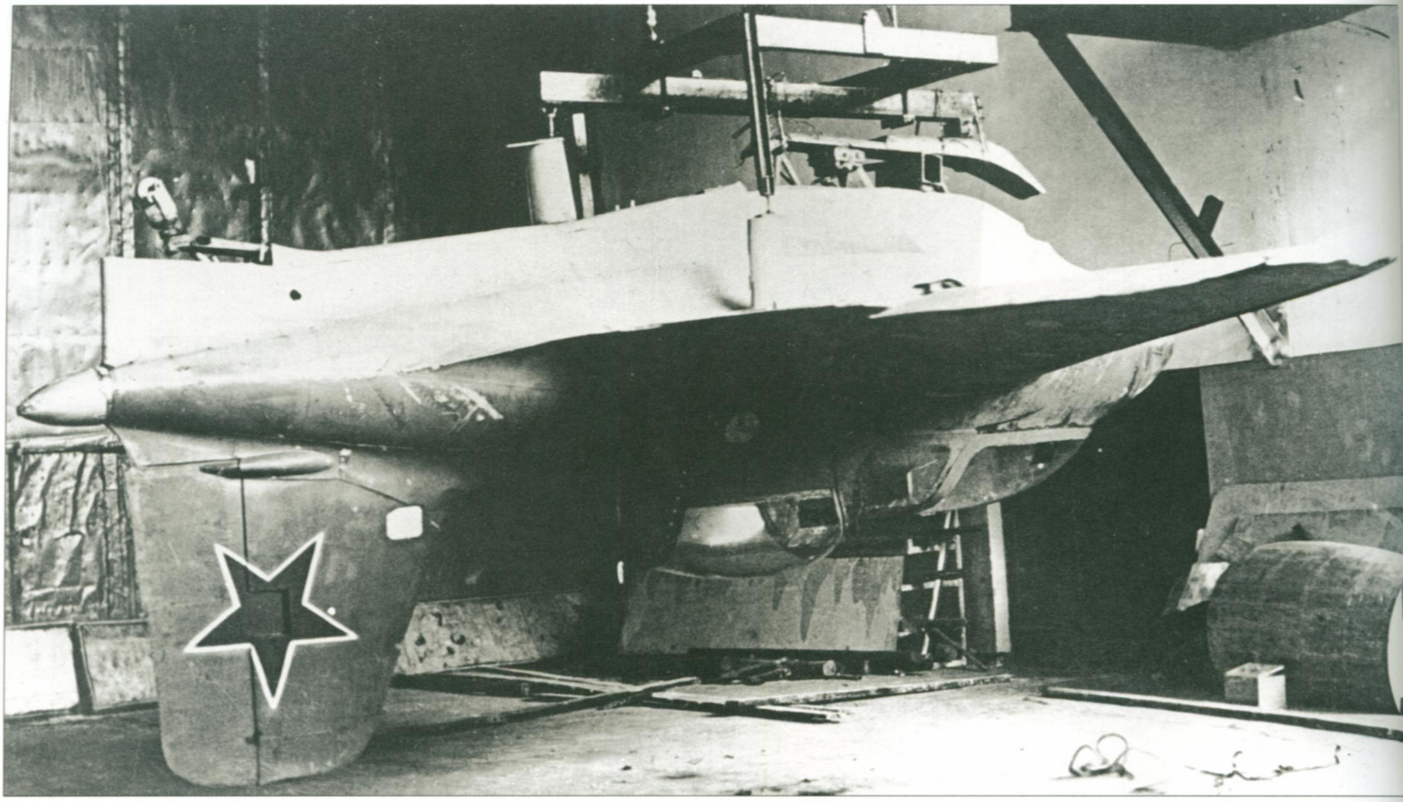
A drawing of the Me 163S (Schulflugzeug) two-seat trainer from a Soviet test report, showing the aircraft's dimensions.

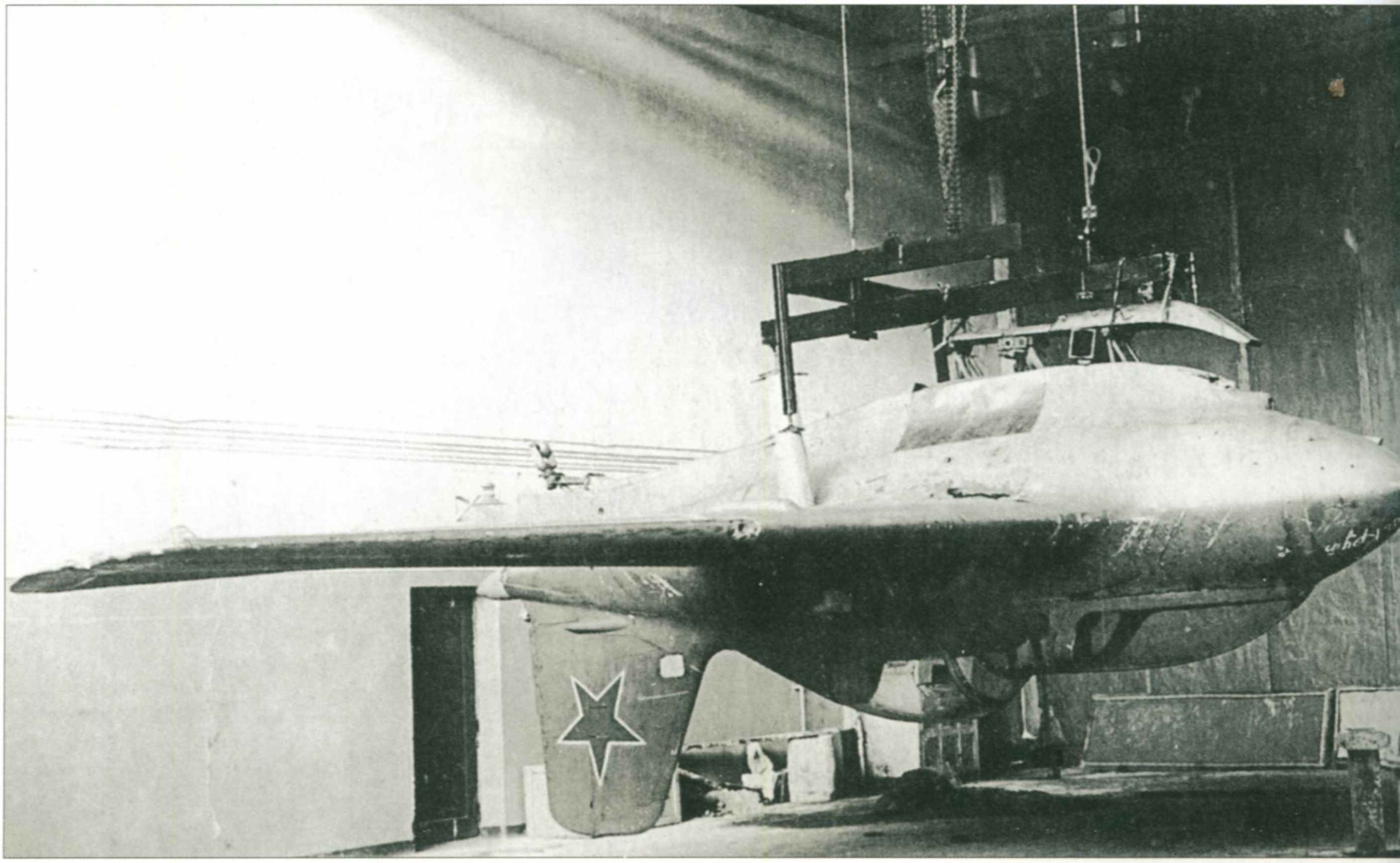


Above: The Me 163S in TsAGI's T-101 wind tunnel. Attachment struts had to be installed under the wings for this purpose. Note the fairing closing the rocket motor nozzle.



The Me 163S hangs inverted in one of TsAGI's shops during static tests, suspended by the wind tunnel mounting struts.



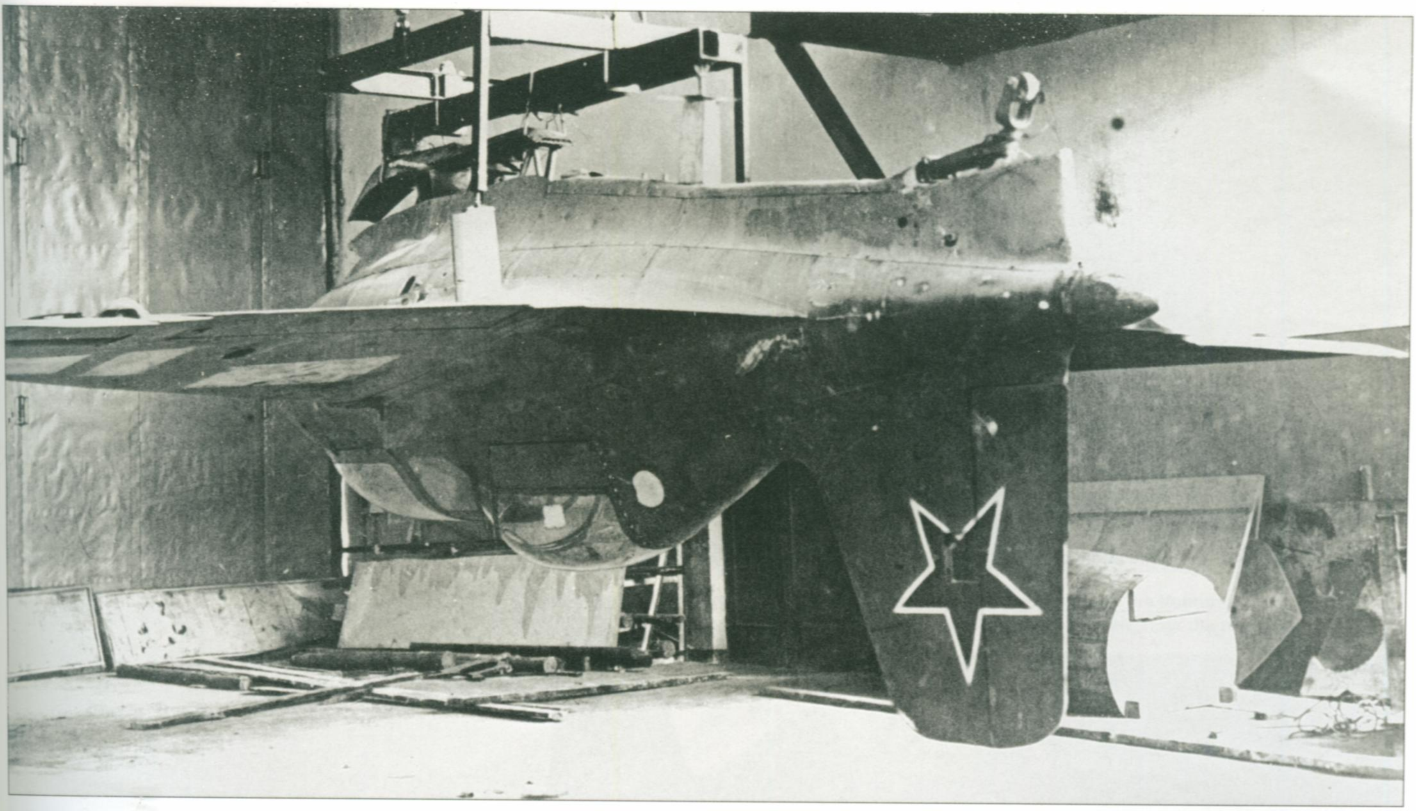


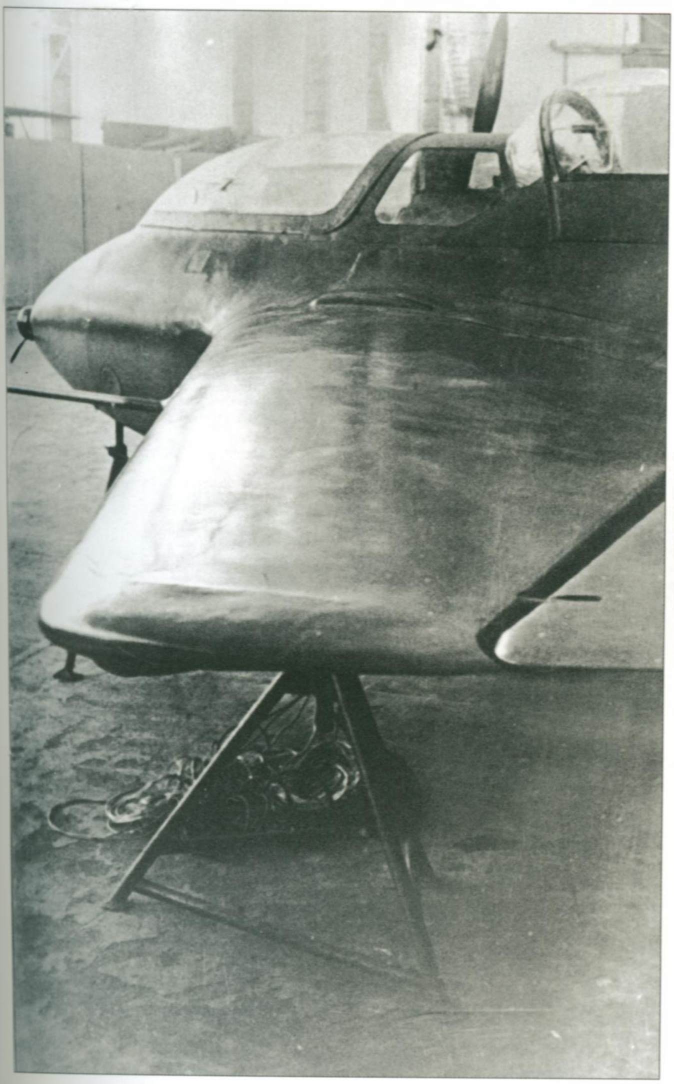
This Page:

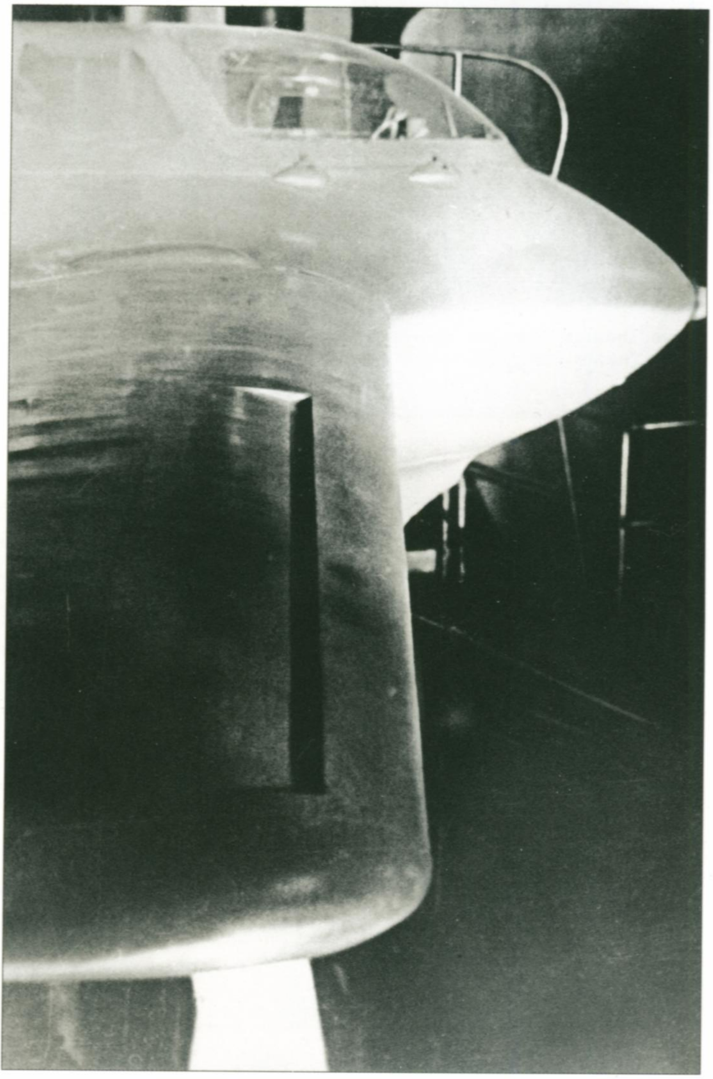
Two more views of the Me 163S undergoing during structural strength tests at TsAGI.

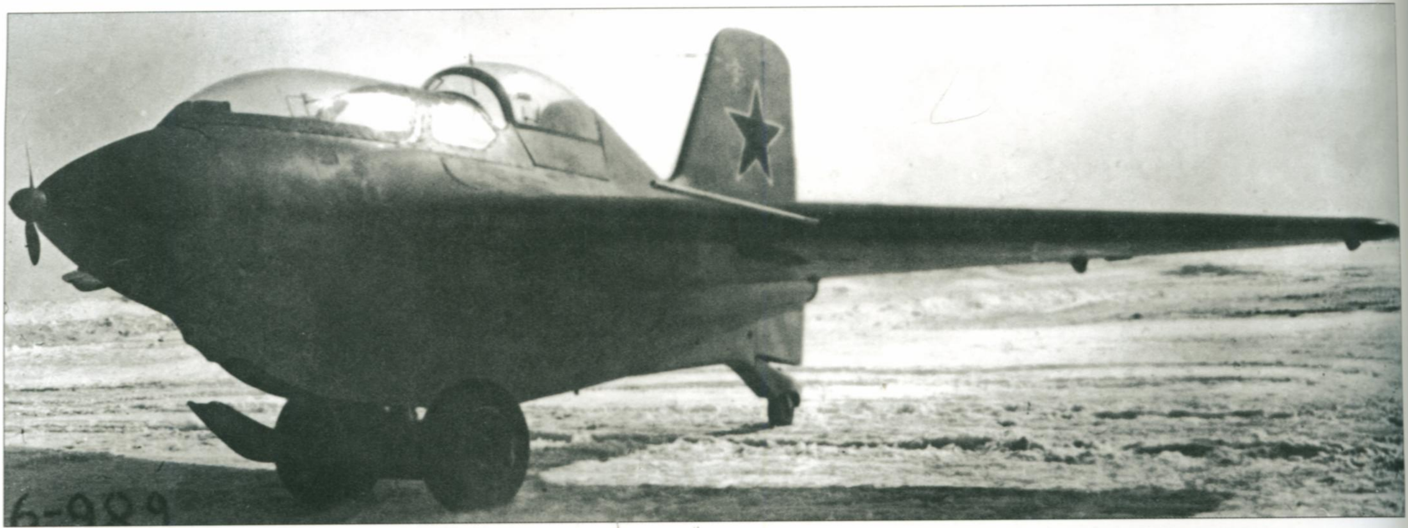
Opposite Page:

Top: Yet another view of the inverted Me 163S. Note that the fairing of the tailwheel strut and the tyre have been removed.
Bottom left: The Me 163S trestled at TsAGI. This view shows the tandem canopies with a transparent section in between.
Bottom right: The Me 163's wings had strong leading-edge sweep and fixed leading-edge slots over much of the span.

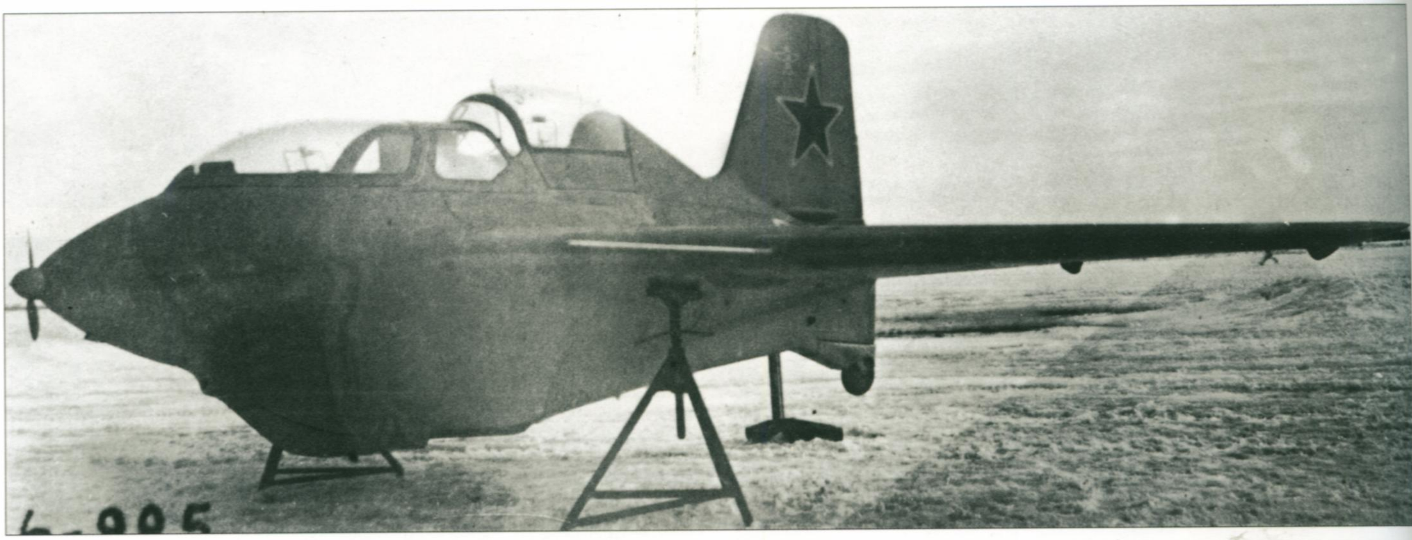




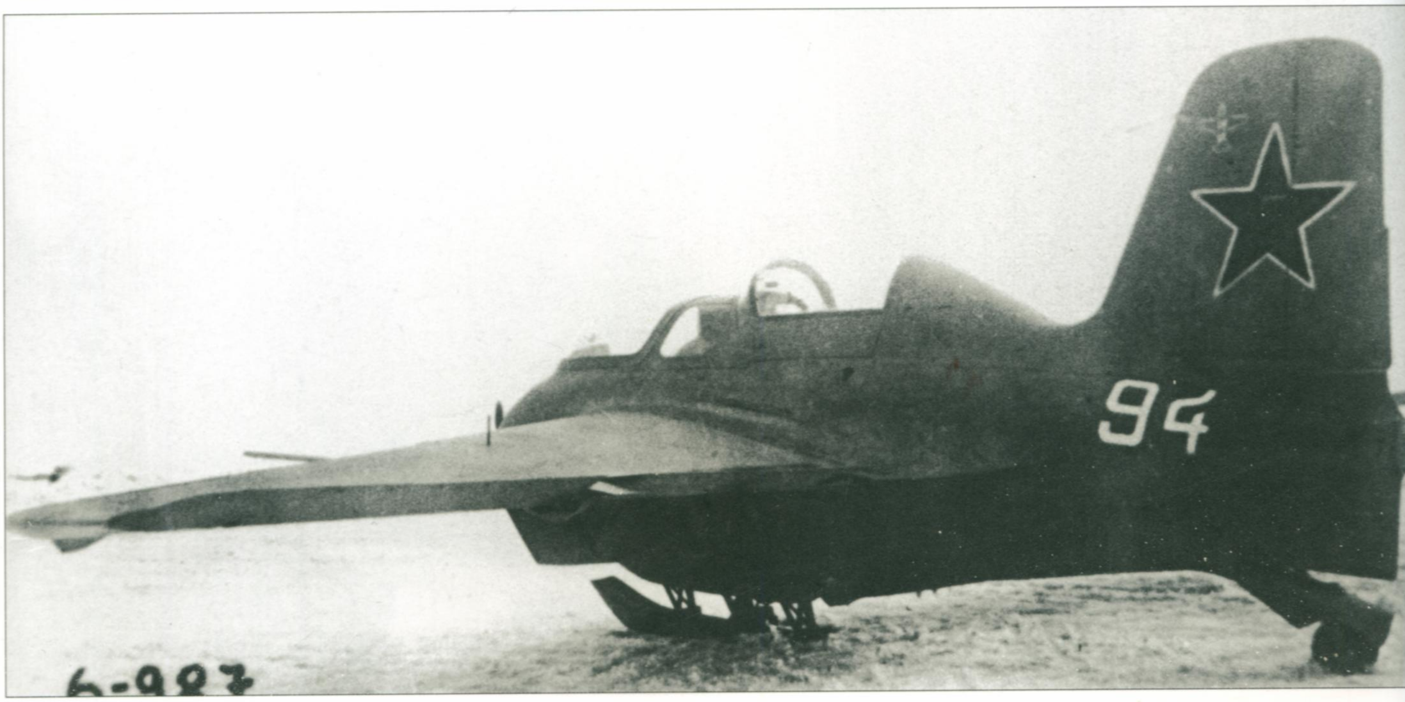


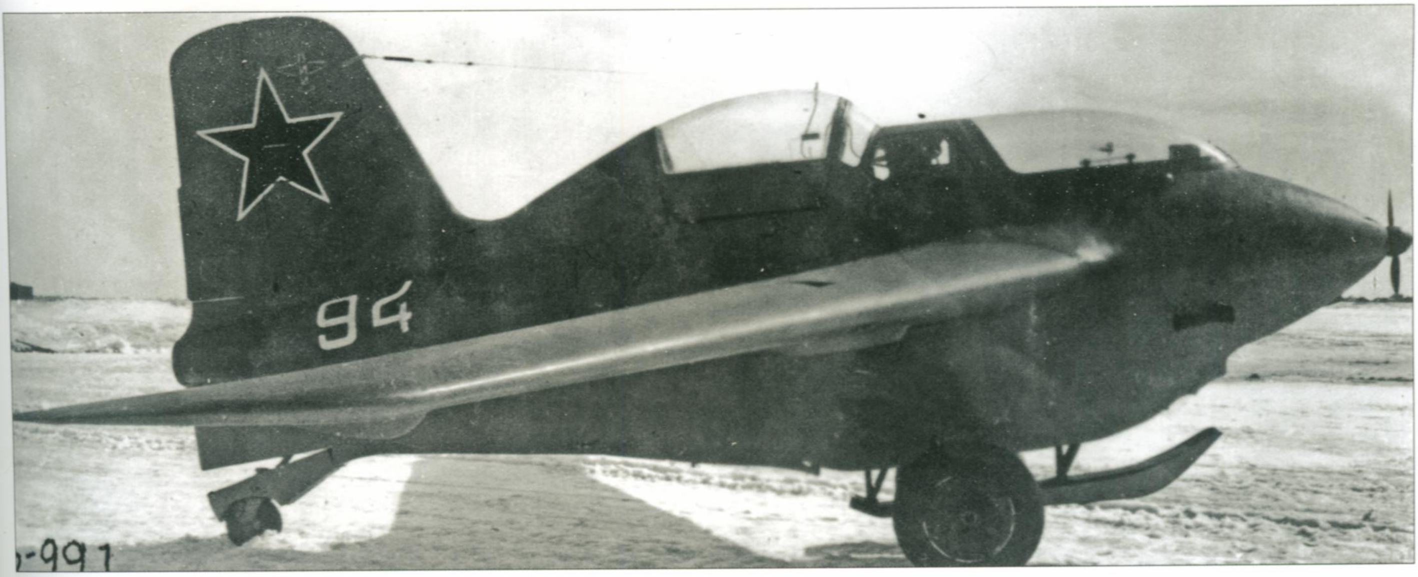


Above: The Me 163S sits on the snow-covered LII airfield in Ramenskoye in take-off configuration.

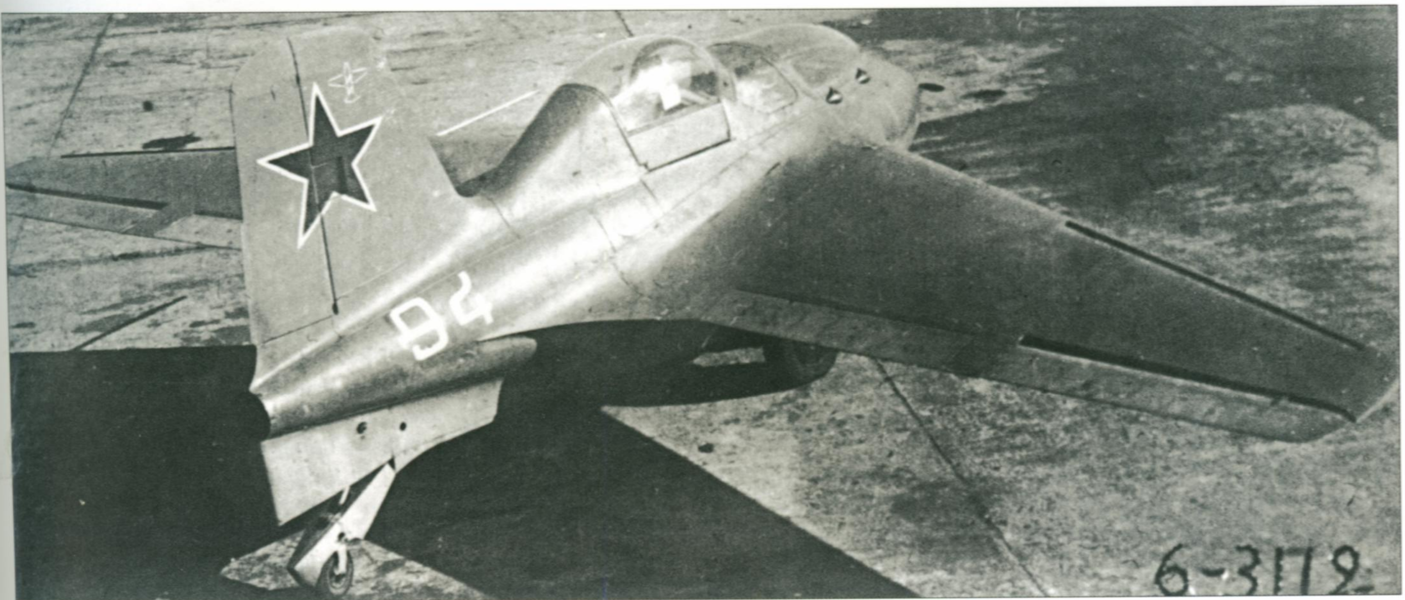


Above: The same aircraft in flight configuration.
Below: The Me 163S gained the serial '94 White' in the course of the trials at LII. The skid was wide enough for the aircraft to sit in a wings-level position.

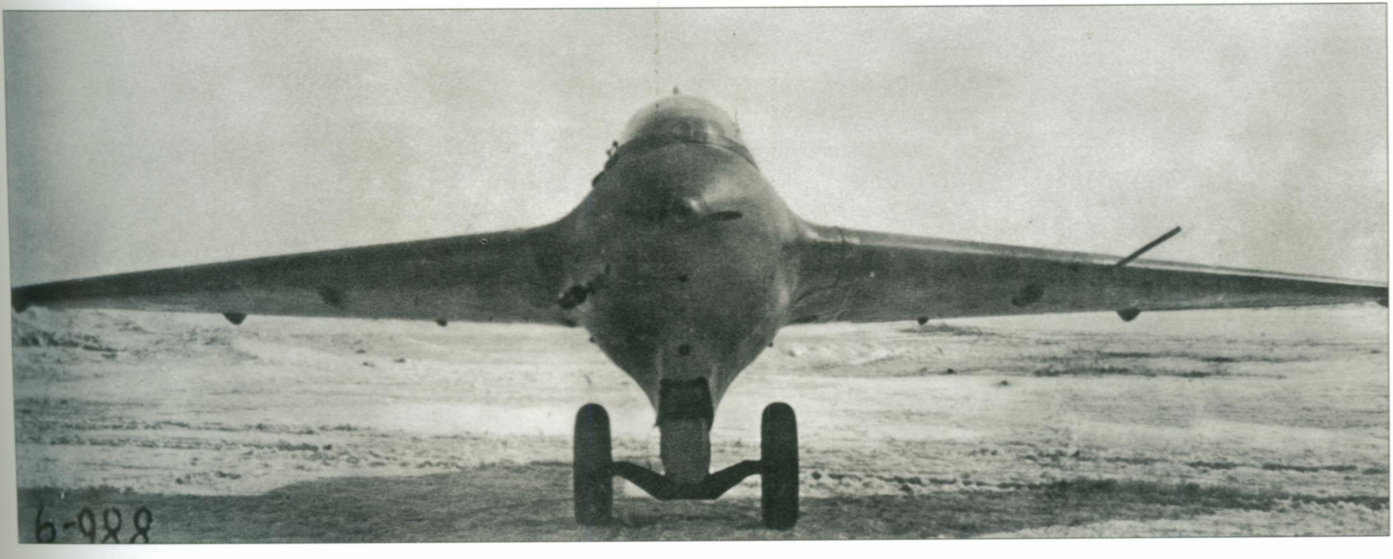




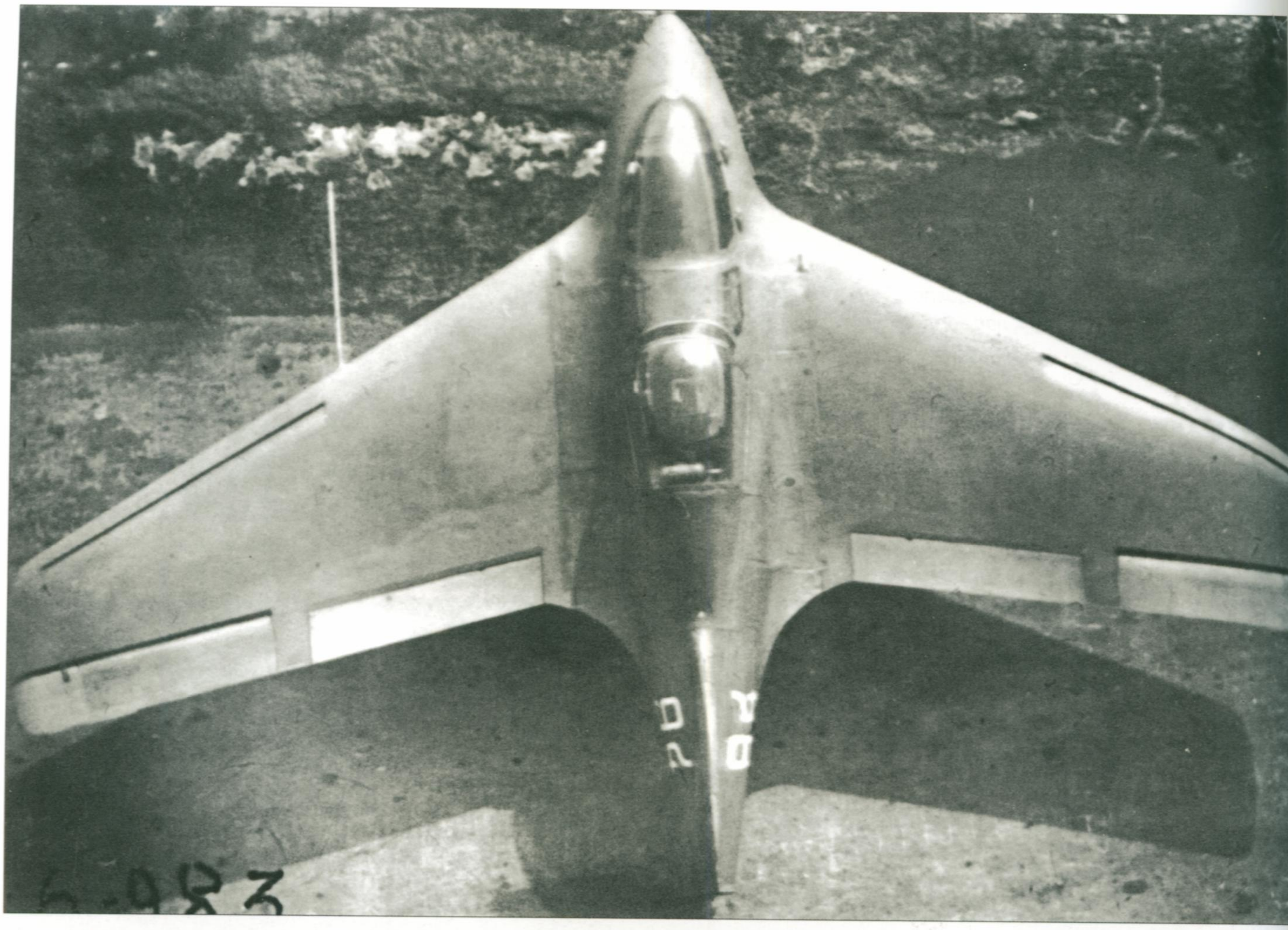
Above: Another view of '94 White' on its take-off dolly at LII. The addition of the instructor's cockpit necessitated the relocation of the Venturi tube from the fuselage spine to the starboard side of the nose. Note LII's then-current badge (the letters 'ЛИИ' inside the silhouette of an aircraft) near the red star on the fin.



Above: Three-quarters rear/upper view of the Me 163S. Both canopies opened to starboard.

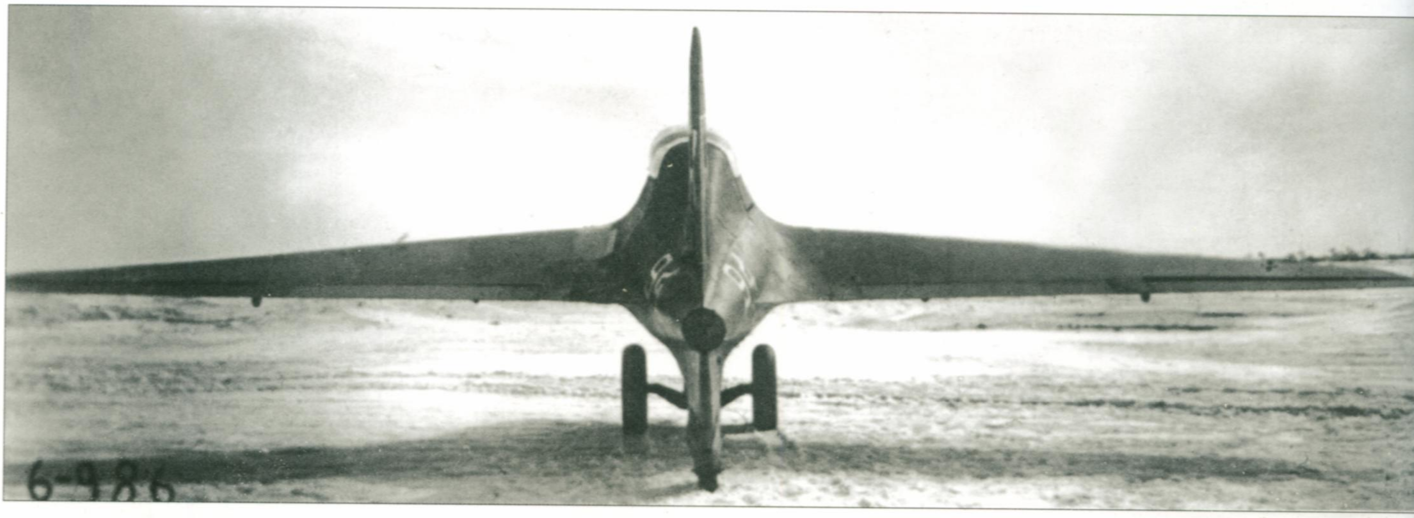


This front view underscores the dolly's extremely narrow wheel track which made the take-off a tricky procedure.



Above: A fine upper view showing the Me 163's distinctive arrow-like planform and the proportion of the leading edge occupied by the slots.

Every one of the People's Commissars responsible for a branch of the defence industry was expected to take a decision either to copy some captured specimen of hardware, or to refrain from such copying. This question was extremely acute, as exemplified by the wrangling around the Air Force's proposal to put a copy of the Me 262 jet fighter into production. The chiefs of NKAP were at odds over this subject: one Deputy People's Commissar (Pyotr V. Dement'yev) supported the idea of copying, while another (Aleksandr S. Yakovlev) was against it. It cost great pains to put out the impending scandal: as a compensation for the refusal to copy the German specimen several designers pledged to develop indigenous aircraft with higher performance. However, this confrontation had grave consequences for People's Commissar of Aircraft Industry Aleksey I. Shakhoorin. Together with Red Army A Force Commander-in-Chief Aleksandr A Novikov and the Air Force's Chief Engineer A K. Repin, as well as several other prominent figures, he was removed from his post in earl 1946 and persecuted. Among other things, thi group was accused of alleged unwillingness t build and master the new jet aircraft.

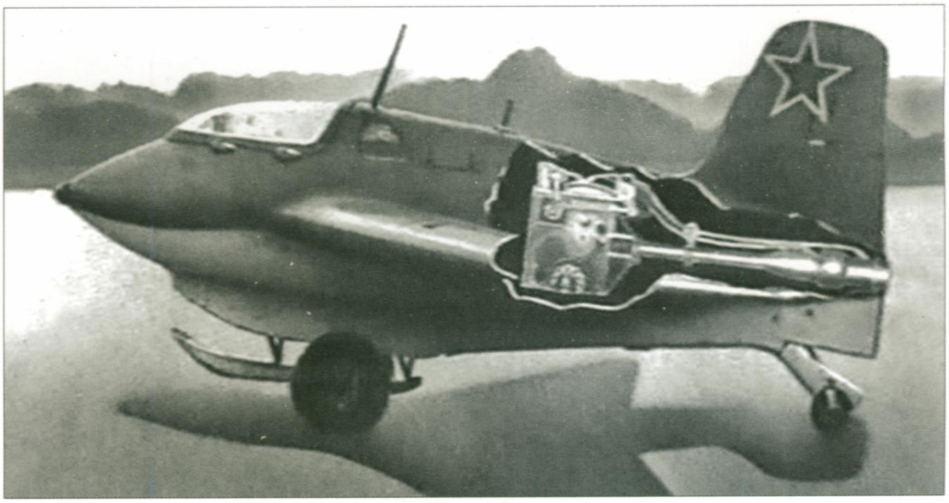


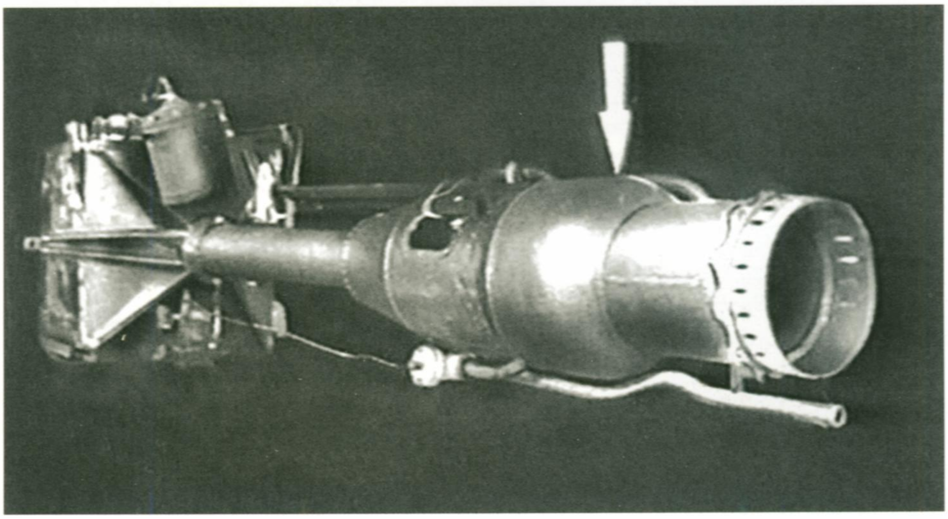
A rear view of the Me 163S.

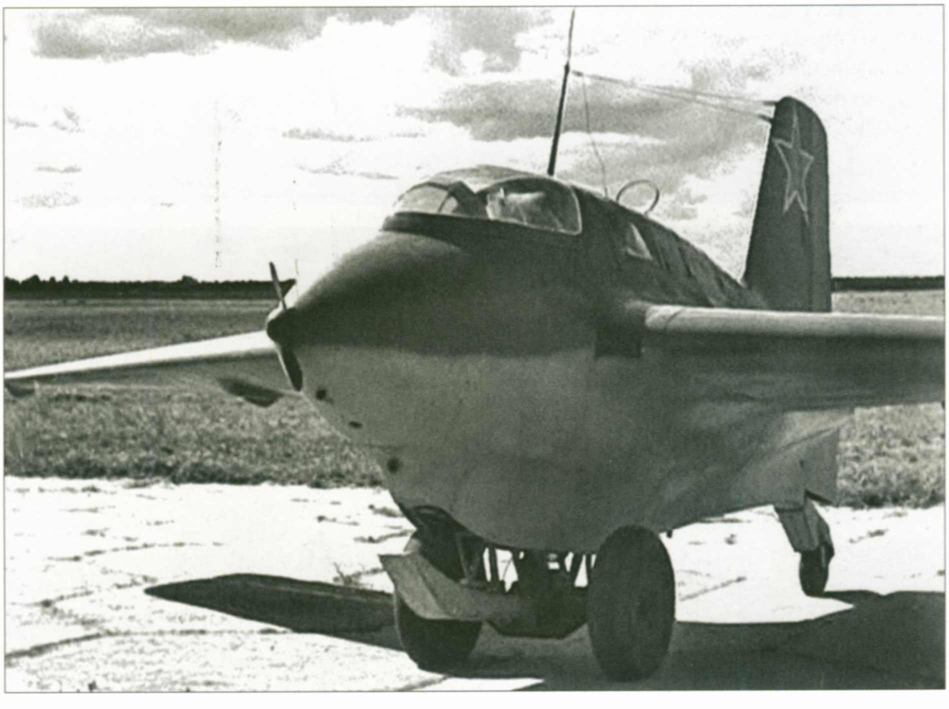
As for the captured hardware, the jet aircraft that fell into Soviet hands included ten Me 163 Komet rocket-powered fighters; of these, three were single-seat Me 163Bs used in combat and seven were Me 163S two-seat trainers. Only one aircraft proved to be in airworthy condition. The interceptors and the trainers were sent for examination and testing to the Flight Research Institute (LII), the Soviet Air Force State Research Institute named after Valeriy P. Chkalov (GK NII VVS – *Gosoodarstvennyy krasnoznamyonnyy naoochno-issledovatel'skiy institoot Voyenno-vozdooshnykh seel*) and TsAGI.

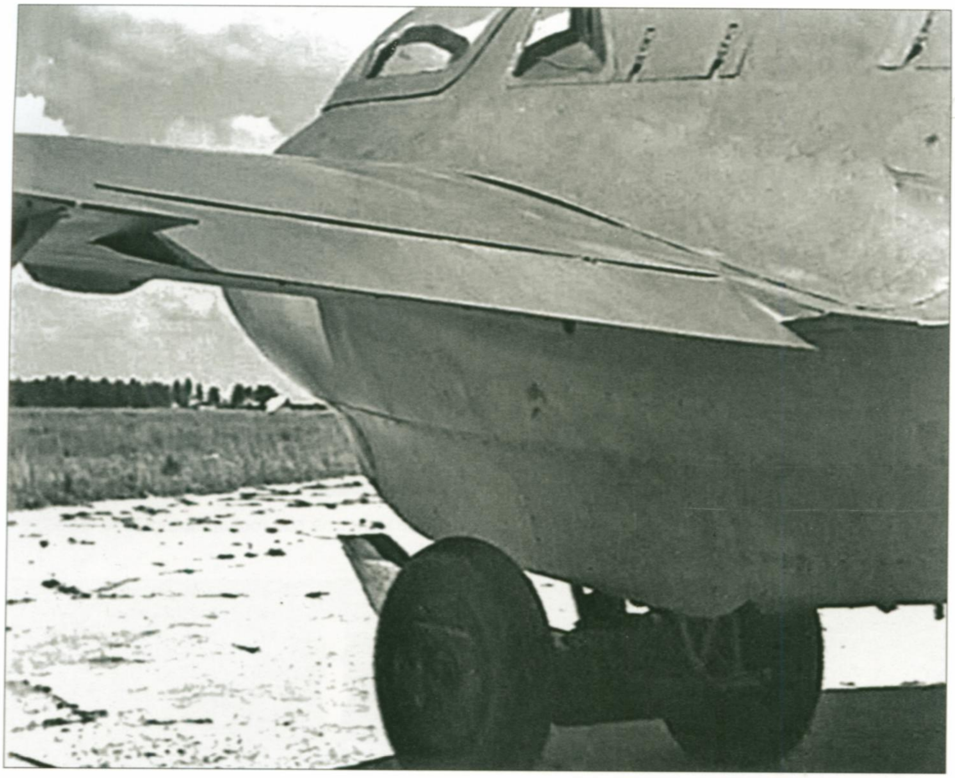
The Me 163 featured a tailless flying wing layout which was unusual for Soviet designers; its wings had a sweepback of 23.3°, a camber of 6°30' and a Lockheed-type slot on the leading edge. The interceptor was powered by a Walter HWK 109-509 liquid-fuel rocket motor which yielded a thrust of 1,750 kgp (3,860 lbst) at sea level. However, this motor required special propellants known as *T-Stoff* (80% hydrogen peroxide with oxyquinoline or phosphate added as a stabiliser) and *C-Stoff* (a 30% hydrazine hydrate solution in methanol), which were unavailable. In October-November 1945 the Air Force Command made an attempt to order from the People's Commissariat of Chemical Industry 23 tonnes (50,700 lb) of *C-Stoff*, 7 tonnes (15,430 lb) of *T-Stoff* and 50 kg (110 lb) of a solid catalyst (potassium permanganate with some admixtures which was used for the decomposition of hydrogen peroxide). This amount was calculated to be sufficient for ten flights with the engine ignited and for five engine firings on the ground.

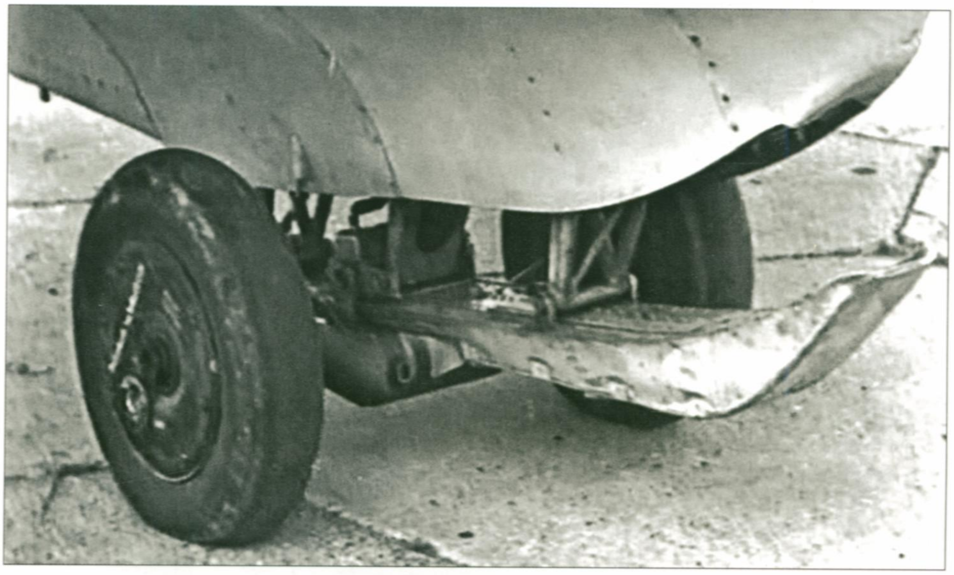
However, this attempt failed. The flight tests of the Me 163 were lagging behind schedule and the machine was flown only in glider mode (without igniting the engine), being towed aloft by another aircraft. The official reason for the decision to refrain from powered test flights was that the HWK 109-509 had not passed bench tests in the USSR and no test results were available for making a conclusion as to whether any of the available rocket motors was suitable for flight testing. Mark L. Gallai was the project test pilot; he later wrote interesting memoirs about these flights. *'It* (the rocket motor – *Auth.*) *ran on hydrogen peroxide, and it devoured this food, quite alien to us, in such quantities that it would be necessary to take special measures for expanding the production of hydrogen peroxide if we were to satisfy its appetite'* – Gallai recalled. To determine the stability and handling characteristics, the two-seat Me 163S, which, because of its short and stocky silhouette, was dubbed *Karas'* (Crucian) in the USSR, was towed to the required altitude on a long cable by a Tu-2 and then released. During the descent it went through all the

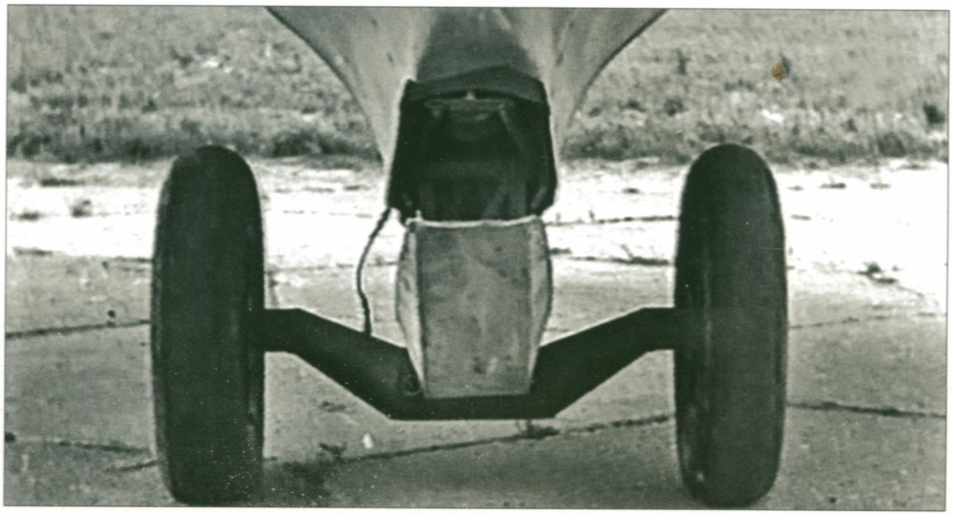

Above: This cutaway drawing shows the location of the Walter HWK 109-509 rocket motor in the Me 163's fuselage.


Above: The HWK 109-509 was a rather bulky engine. The combustion chamber (indicated by the arrow) is at the extreme rear, with the steam/gas generator and turbo pump unit at the front.


A single-seat Me 163B at GK NII VVS.







Left: Close-up of the Me 163B's port flap, with a small fixed trailing-edge portion between it and the aileron. Note the bulletproof windscreen visible through the blown Perspex canopy and the equipment bay access covers with tension locks aft of the cockpit.

Below left: Close-up of the take-off dolly and the main landing skid; the latter features an electrically actuated lock for the dolly's axle.

Bottom left: Front view of the dolly and the skid.

predetermined flight modes. Mastering this aircraft proved to be no easy task even for experienced glider pilots – the Komet was much heavier, much more sluggish and had a much greater sink rate than most unpowered aircraft. Although one of the flights ended in an accident due to an incorrect CG position, the test report noted that *'a rationally chosen aerodynamic layout and the design features of the tailless aircraft afford it sufficiently good longitudinal and lateral stability and controllability in the area of subsonic flight speeds. This bears witness to the possibility of using this layout as a possible design configuration of a high-speed aircraft'*. True, this appraisal was 'watered down' by the following remark: *'The layout under investigation does have certain drawbacks. Among these one should mention a considerably higher minimum control speed, as well as higher take-off and landing speeds, as compared to conventional aircraft with an equal wing loading, and a general configuration of the wings which is not quite satisfactory for a high-speed aircraft (a small sweepback angle, the presence of a slot and pronounced camber, a thick airfoil)...'* However, at the same time Lieutenant-Colonel V. Ye. Golofastov, the fighter's project test pilot at GK NII VVS, came to the conclusion that the Me 163 tailless single-seat fighter behaved largely identically to conventional fighters in gliding flight and while performing the principal aerobatic manoeuvres.

Lacking the necessary test facilities, the engineers of NII-1 limited their efforts to dismantling the engine, preparing arrangement drawings and making anew the calculations pertaining to the German engine. In 1945 the staff of NII-1 developed and put into operation test rigs for the testing of steam/gas generators, turbopump units, injection nozzles and liquid-fuel rocket motors as a whole.

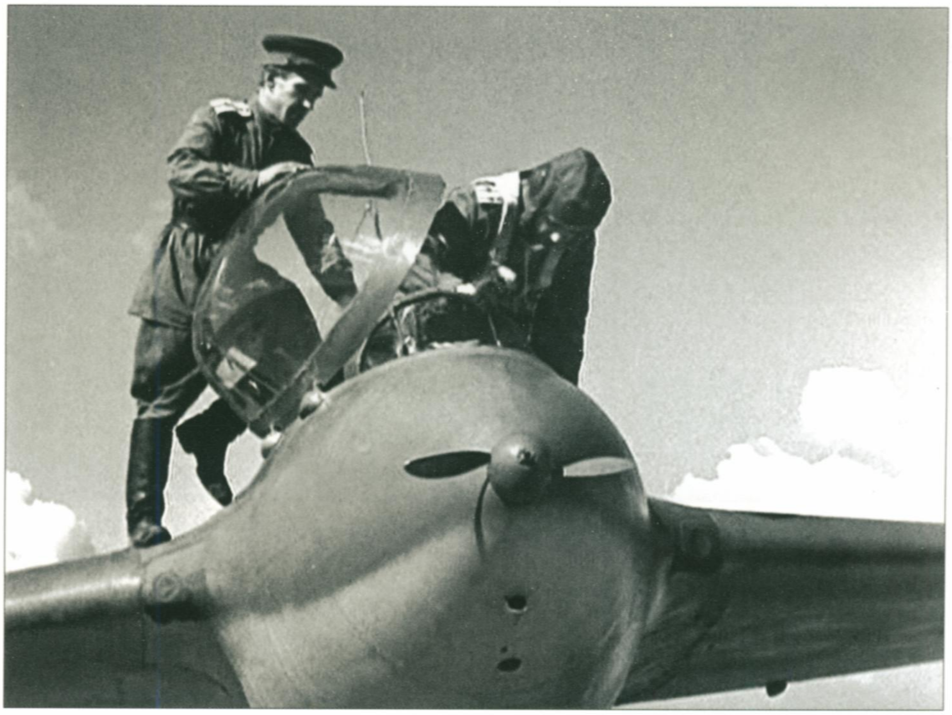
In the meantime, the single-seat Me 163B interceptor and the two-seat Me 163S trainer proved to be simple in handling. The Me 163B performed all aerobatic manoeuvres relatively easily. Difficulties arose primarily during take-off and landing due to the Komet's unconventional undercarriage with its jettisonable take-off dolly and extendable landing skid. In the concluding part of the state trials protocol, GK NII VVS pointed out that *'...the captured German Me 163B aircraft*

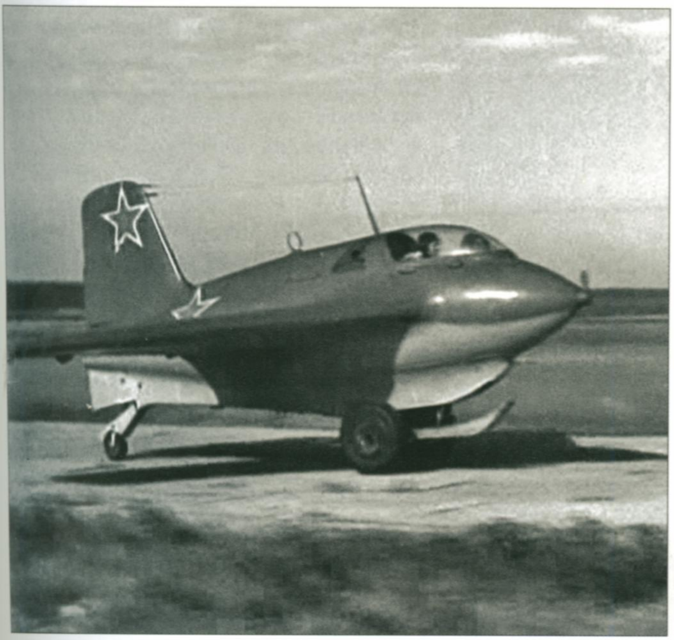
Above: Mark L. Gallai dons his flight helmet before a flight in the Me 163B.

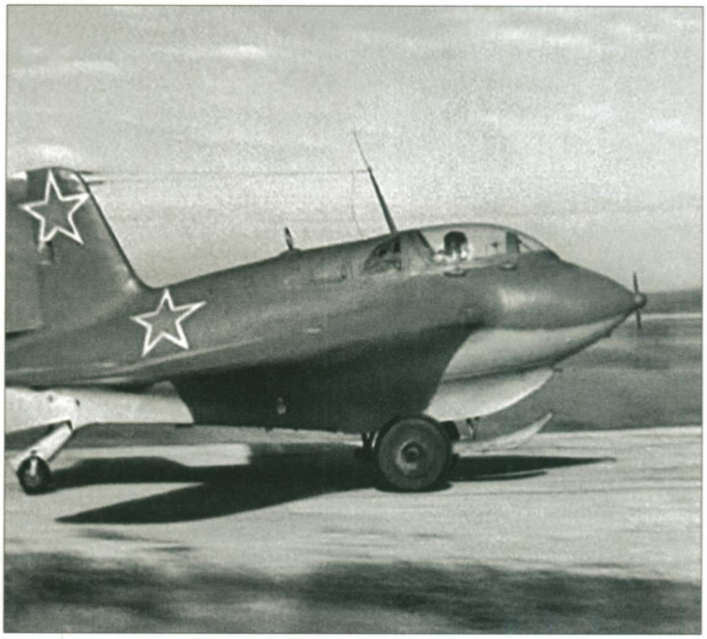
Right: Gallai climbs into the Me 163B's cockpit. Note the faired-over gun ports in the wing roots and the odd angle of the generator drive vane's blades which appear to be bent out of shape.

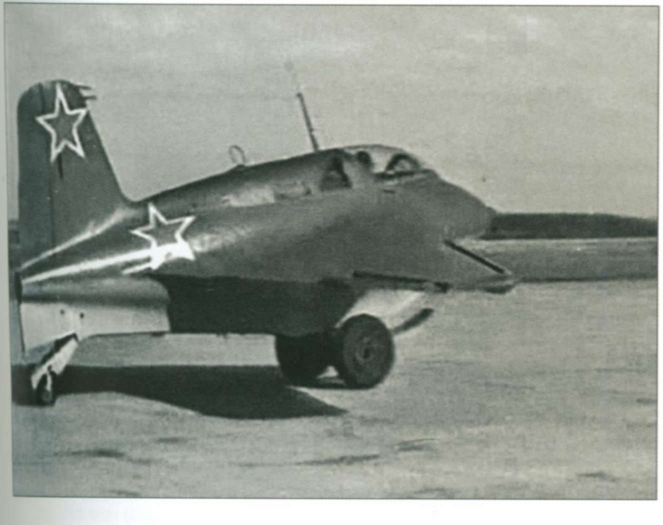
Below, below right and bottom: Sequence of stills from a cine film showing the Me 163B taking off under tow, with Gallai at the controls.

Bottom right: The Soviet Me 163B in gliding flight.







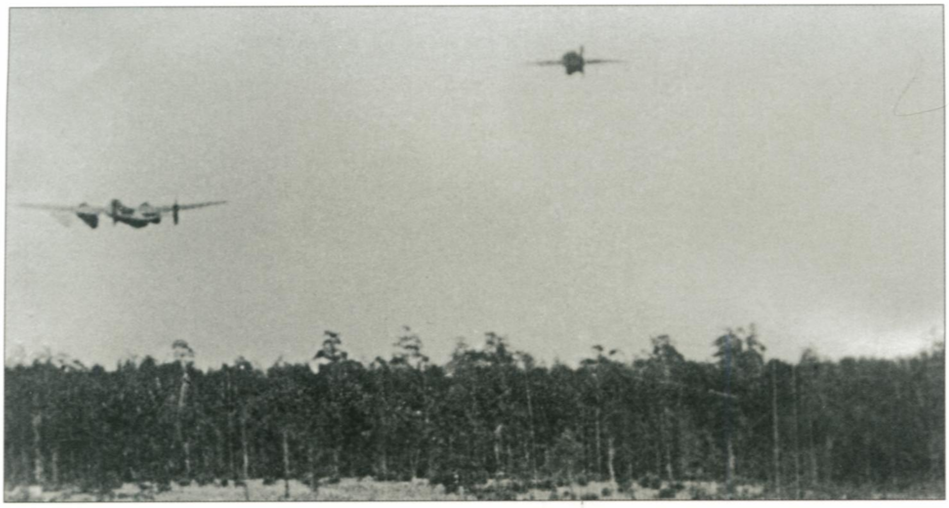


featuring a tailless layout […] has been fully developed as regards controllability and stability in unpowered flight'.

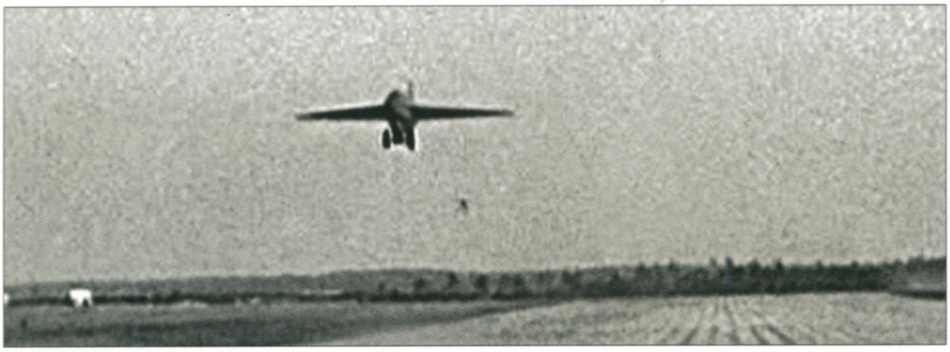
It was impossible to undertake a practical assessment of the Me 163's combat qualities. However, according to German data, it could climb to 12,000 m (39,360 ft) in 3.5 minutes and attain a maximum speed of 900-950 km/h at altitudes in excess of 4,000 m (13,120 ft).

It was equally impossible to copy the aircraft without thoroughly studying it. Yet this did not imply that the idea of using a rocket-powered fighter for intercepting heavy bombers at high altitudes was unsound – all the more so since the Germans had solved this problem and even put into series production a fighter powered by a liquid-fuel rocket motor. Materials on the testing of the Karas' were made available to the leading Soviet design bureaux engaged in fighter design, but they had a much lesser influence on the development of Soviet jet aircraft than had the turbojet-powered Me 262. The specialists of the Soviet aircraft industry, of GK NII VVS, LII and TsAGI carefully studied the German experience in repulsing the raids performed by Allied heavy bombers; as a result, when the first post-war plan for prototype aircraft construction was drafted in 1946, Commander of the Air Defence Fighter Aviation Colonel-General I. D. Klimov raised the issue of organising the development of indigenous rocket-powered interceptors.

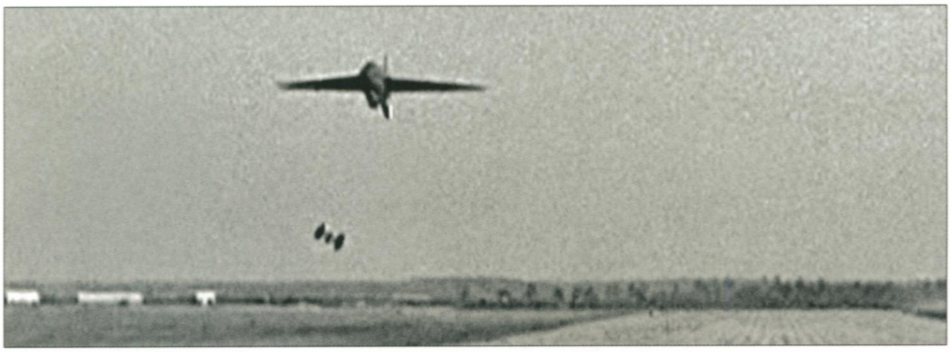
The leaders of NKAP took this wish into account when preparing the said plan. A Soviet Government directive entrusted two design bureaux with the development of rocket-propelled interceptors to almost identical requirements. OKB-155 led by Artyom I. Mikoyan was tasked with designing and building an experimental single-seat interceptor with a liquid-fuel rocket motor and a pressurised cockpit, while OKB-301 led by Semyon A. Lavochkin was to create a similarly powered experimental single-seat fighter armed with rocket projectiles and fitted with a ranging radar (or 'radar sight').

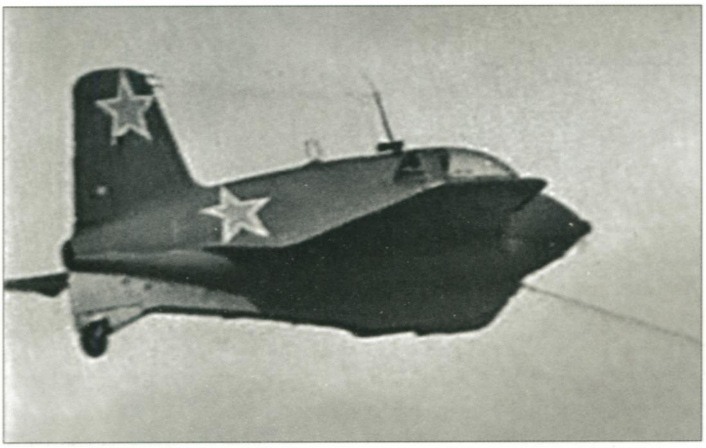


Above: The Me 163B a few seconds after becoming airborne on a towed test flight; the fighter has climbed appreciably higher than the Tu-2 bomber used as the glider tug. Both aircraft are in 'clean' configuration.

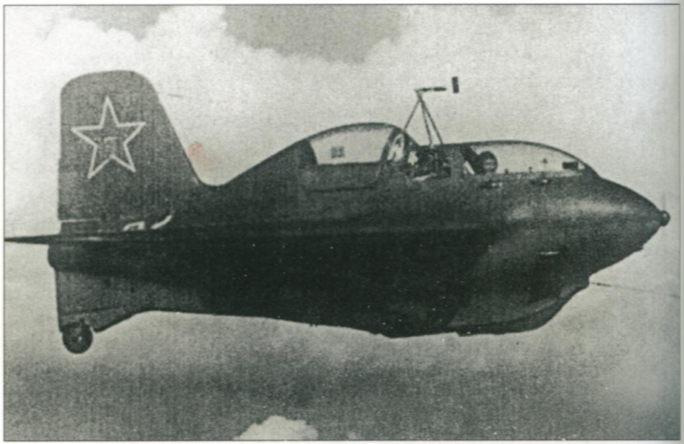


Above: The Me 163B a few seconds after becoming airborne on a towed test flight, with the take-off dolly still in place … a second later (Below), the dolly is jettisoned and away. The release took place at a sufficiently high altitude to prevent the dolly from striking the aircraft on the rebound.





The same aircraft seen from a chase plane as it is towed to altitude by the Tu-2. Note where the towing line is attached.



Me 163S '94 White' being towed to altitude. Note the sensor pertaining to the test equipment on a tripod-like structure ahead of the (vacant) rear cockpit.

Chapter 5

The Fighter Makers

Lavochkin's and Mikoyan's Contribution

Lavochkin '162' Interceptor (Project)

Bearing in mind the eminent success scored during the war by the fighters emanating from the Lavochkin OKB, this design bureau continued to be 'in the limelight' during the first post-war years. Like the design bureaux led by Aleksandr S. Yakovlev and Artyom I. Mikoyan, the OKB-301 design bureau headed by Chief Designer Semyon Alekseyevich Lavochkin began receiving high-priority tasks. One of these called for the development of a fully-fledged interceptor capable of detecting and destroying enemy bombers in daytime and at night under all weather conditions. The task was all the more complex because of the fighter's short endurance; nor could it be tackled without the use of a special gun ranging radar – or, in the Soviet terminology of the day, radar sight.

Under the terms of the prototype aircraft construction plan endorsed by the Soviet Council of People's Commissars (Government) directive No.472-193 on 26th February 1946, OKB-301 was entrusted with designing and building an experimental single-seat fighter powered by a liquid-fuel rocket motor, armed with rocket projectiles and equipped with a radar sight. The leaders of NKAP had, like the leaders of the German aircraft industry in their time, fell for the idea of creating a cheap mass-produced interceptor. The aircraft was required to have the following performance:

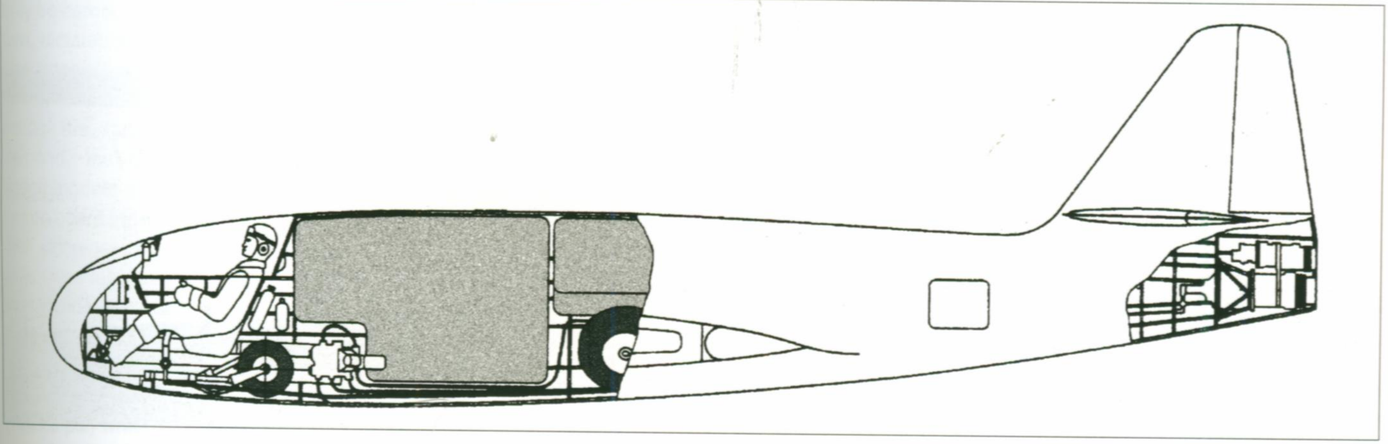
- maximum speed at sea level – 1,050 km/h (653 mph);
- maximum speed at an altitude of 5,000 m (16,480 ft) – 1,100 km/h (684 mph);
- endurance at maximum engine thrust – 6 minutes;
- endurance at minimum engine thrust – 21.5 minutes;
- service ceiling – 18,000 m (59,060 ft).

The fighter's armament was to comprise six 82-mm (3.22-in) TRS-82 rockets (*__toor__boreak__tiv__nyy sna__ryad__* – spin-stabilised rocket projectile). The interceptor was intended for the defence of civil and military installations; it was to be guided towards the target from the ground via data link, zeroing on to the target at the final stage of the intercept by means of the on-board radar. The aircraft was to be submitted for flight testing by 1st May 1947.

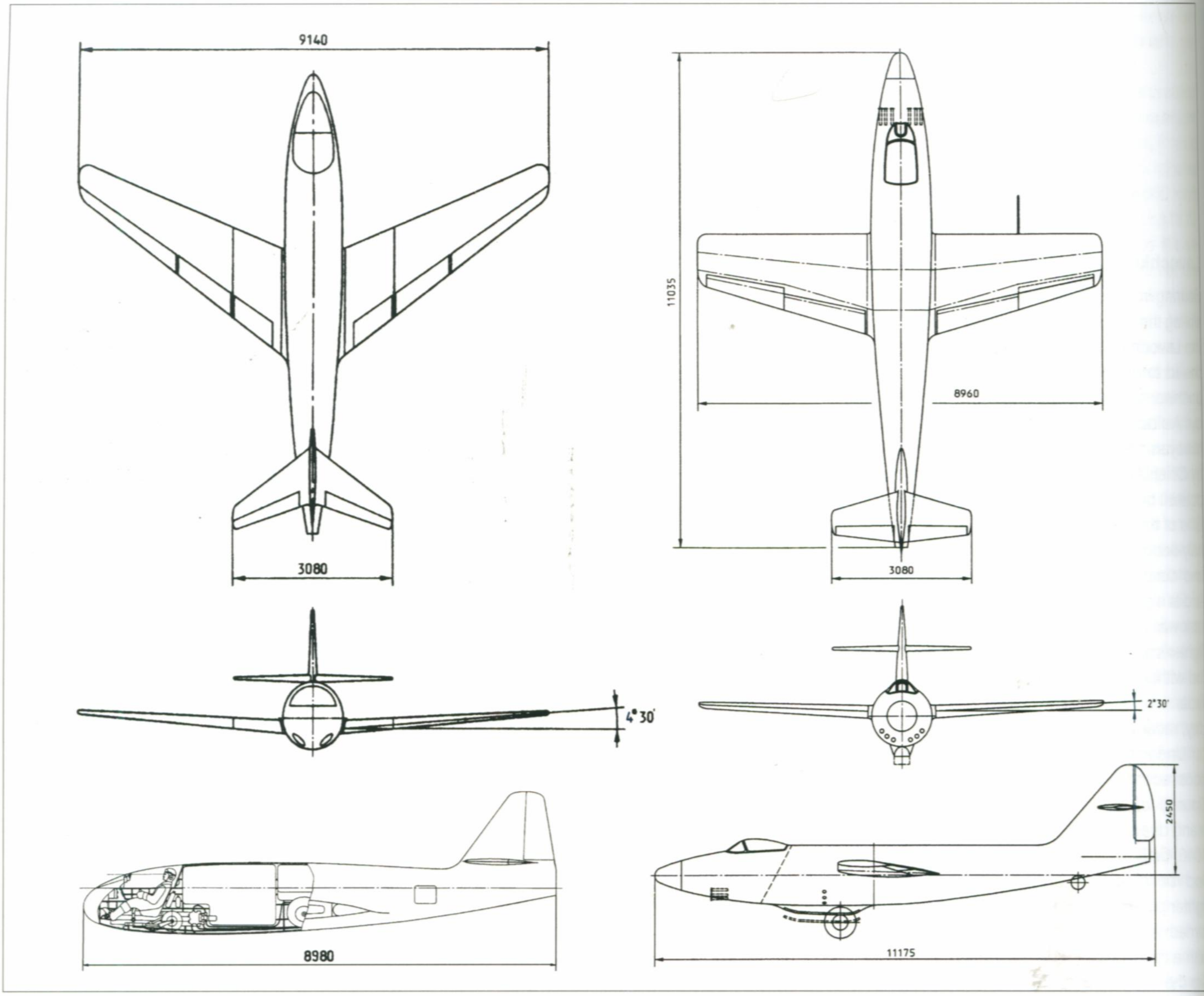
In the same year of 1946 the NII-17 avionics house (Research Institute No.17) started development work on two types of airborne radars intended for interception and sighting. The first of these, the Toriy-1 (Thorium), was designed for installation in two-seat fighters where one of the crewmembers would act as a weapons systems officer; the other model, the Toriy-2, was intended for single-seat fighters. In both cases A. B. Slepushkin was the Chief Designer; he had been awarded the prestigious Stalin Prize for his previous work. The Toriy-2 radar was tailored specifically to an aircraft then under design in Lavochkin's OKB-301; representatives of the Lavochkin OKB had endorsed the advanced development project of this radar as quite satisfactory.

By the end of 1946 designers at OKB-301 had completed the ADP of the interceptor fitted with the Toriy-2 radar. Known in-house as 'aircraft 162', this was an all-metal cantilever monoplane with mid-set wings. Initially the interceptor project featured a very bold aerodynamic layout incorporating forward-swept wings (FSW) and swept-back tail surfaces; it was obviously inspired by German projects documents on FSW research that had been captured by Soviet troops. Furthermore, when the projecting of the '162' interceptor was in progress, German specialists interned in the USSR were engaged in the work on the '346' (DFS 346) rocket-propelled aircraft dealt with later in this book, and the materials on this machine were also made available to OKB-301. Nevertheless, the designers had to give up the FSW layout and to project an aircraft with conventional unswept wings having a thickness/chord ratio of 12% (similar wings had been designed somewhat earlier for Lavochkin's turbojet-powered '152' fighter).

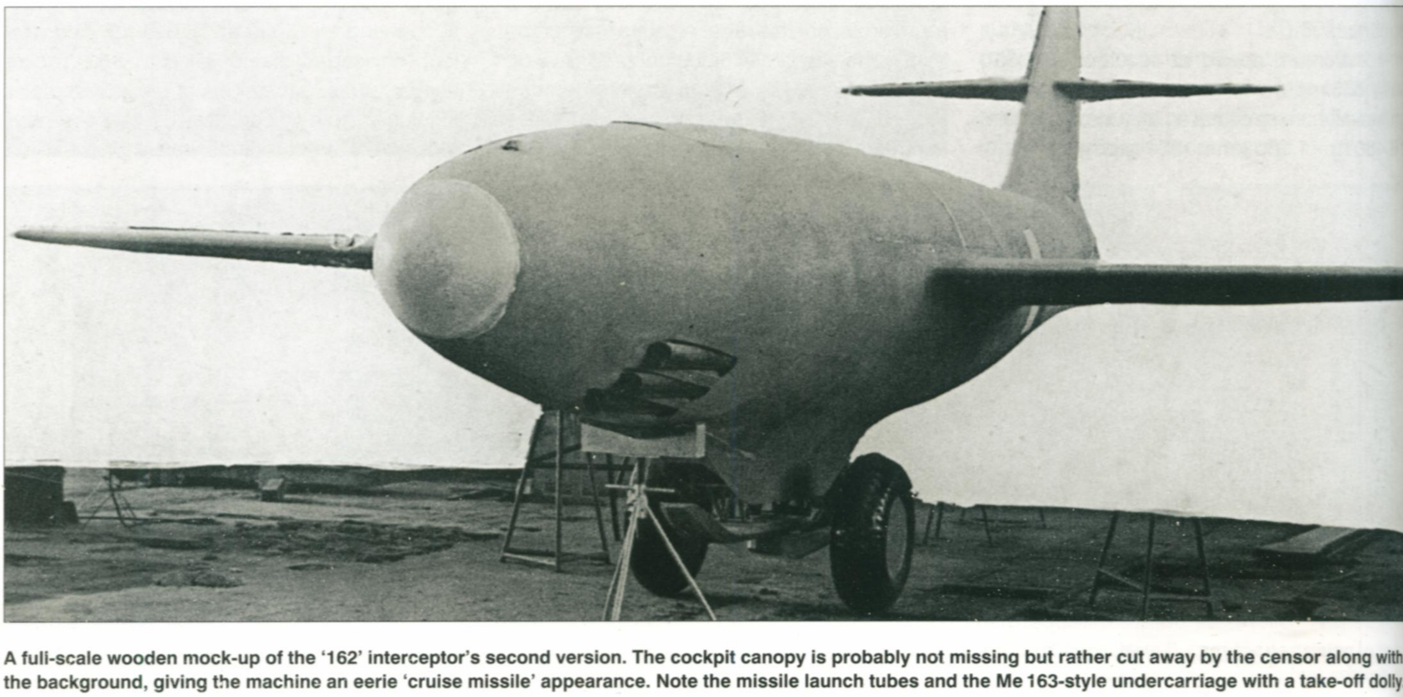
The aircraft had a pressurised cockpit with front armour protection; pressurisation was indispensable for reaching the specified operational altitude. The aft fuselage housed an RD-2M3V twin-chamber liquid-fuel rocket motor designed by L. S. Dooshkin. The fighter was to take off using a special two-wheel dolly, which was to be jettisoned after lift-off; the landing was to be performed with the help of a special skid undercarriage featuring a protective tailwheel. The design take-off weight was 5,000 kg (11,025 lb), the fuel accounting for 3,000 kg (6,615 lb). The project envisaged fitting six ORO-82 rocket launch tubes to the sides of the interceptor's fuselage (three on each side). It was assumed that, when all six rockets were launched in a



A cutaway drawing depicting the first version of Lavochkin's projected '162' rocket-propelled interceptor. Note the retractable tricycle landing gear.



Above: The original forward-swept wing project version of the '162' (left) makes an interesting comparison with the very different and much more conventional second version. Both versions featured rocket launch tubes buried in the fuselage; the second version was equipped with an AI radar in a nose radome.



A full-scale wooden mock-up of the '162' interceptor's second version. The cockpit canopy is probably not missing but rather cut away by the censor along with the background, giving the machine an eerie 'cruise missile' appearance. Note the missile launch tubes and the Me 163-style undercarriage with a take-off dolly salvo, the probability of at least one rocket hitting the target would amount to 92% at a range of 400 m (1,310 ft) and 82% at a range of 600 m (1,970 ft). The TRS-82 rockets were flawed in one important respect – they had a fairly low maximum speed of 300 m/sec (984 ft/sec), which precluded accurate firing at long range.

Calculations showed that, with a take-off weight of 5 tonnes (11,025 lb), the fighter would require a mere 2.5 minutes to climb to 18,000 m (59,060 ft) – something that was absolutely out of reach for the day's turbojet-powered interceptors. A full-scale mock-up of the interceptor was built, but the designers themselves had grave doubts as to the wisdom of building the actual prototype. Despite the possibility of attaining a high rate of climb, Chief Designer Lavochkin held the opinion that a liquid-fuel rocket motor was not, after all, the best means of propulsion for an interceptor. He insisted that it would be much wiser to develop interceptors powered by turbojets or ramjets – all the more so since long-range bombers were expected to be powered by exactly these types of powerplants which would, accordingly, determine the bombers' operational altitudes.

The annual technical report of OKB-301 for the year of 1946, endorsed by Lavochkin, cited several serious arguments to support the opinion that it was impossible to develop a fully capable combat aircraft powered by a liquid-fuel rocket motor. The first negative factor was the fuel itself – more exactly, the use of nitric acid as the oxidiser. The OKB had already obtained some experience with this highly corrosive fuel component, which was used in the RD-1 rocket booster installed in the La-7R and '120R' mixed-power experimental fighters.

Calculations made by the designers showed that the '162' interceptor would suffer a shortage of electric power supply (mainly intended for the on-board radar) due to the insufficient capacity of the gas generator assembly and the turbine pump unit. In addition, the required amount of fuel could only be carried in very bulky tanks, which, in turn, dictated a bulky fuselage. The propulsion specialists put forward a requirement for an overpressure of 1 bar (14.28 psi) inside the tanks. To comply with this demand, the designers were forced to accommodate a set of compressed air bottles on board the interceptor; this led to a further decrease of the thrust/weight ratio, which was fairly low as it was. Furthermore, the liquid-fuel rocket motor incorporated fairly complicated automatic devices and a multitude of various piping functioning under the working pressure of 50 bars (714.28 psi) which was bound to jeopardise operational reliability. To make matters worse, the AI radar under development failed to attain the required performance. In mid-1947 the Special Committee No.2 under the Soviet Council of Ministers (as the former Council of People's Commissars had been renamed in the meantime), responsible for radar technology, stated that design performance of the Toriy-1 and Toriy-2 radars was inadequate. Development of these radars was discontinued, and NII-17 was tasked with the development of a new radar with higher performance. The straight wings incorporated in the design did not permit the fighter to attain the specified speed of 1,050-1,100 km/h (653-684 mph) with the RD-2M3V liquid-fuel rocket motor.

Bearing in mind all these considerations, as well as the difficulties involved in the practical operation of liquid-fuel rocket motors, Chief Designer Semyon A. Lavochkin took the decision to terminate the work on the '162' interceptor. All efforts of OKB-301 were henceforth concentrated on the development of turbojet-powered fighters.

Mikoyan I-270 Experimental Interceptor (*Izdeliye* Zh)

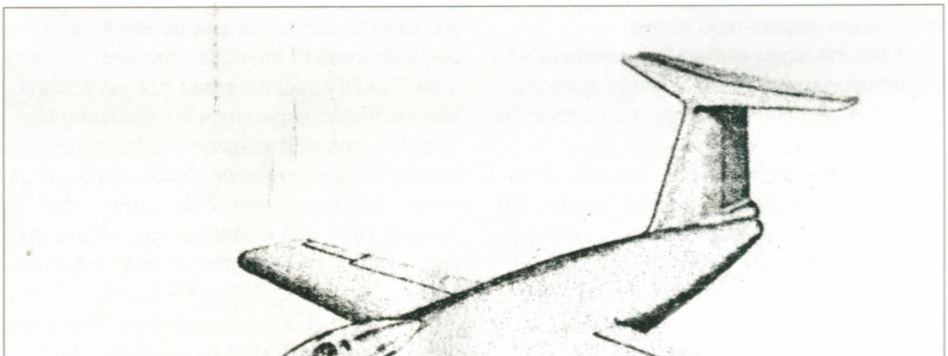
In accordance with the prototype aircraft construction plan endorsed by the Soviet Government's directive No.472-193 of 26th February 1946, OKB-155 led by Chief Designer Artyom Ivanovich Mikoyan was entrusted with designing and building an experimental single-seat interceptor with a liquid-fuel rocket motor and an 'altitude' (that is, pressurised) cabin. The new aircraft was to have the following performance:

- maximum speed, 1,100 km/h (683mph) at sea level and 1,000 km/h (621 mph) at 10,000 m (32,800 ft);
- endurance, 5 minutes at maximum thrust and 18 minutes at minimum thrust;
- service ceiling (with fuel reserves for 1.2 minutes of flight), 17,000 m (55,760 ft);
- climb time to 17,000 m (55,760 ft), 3.2 minutes.

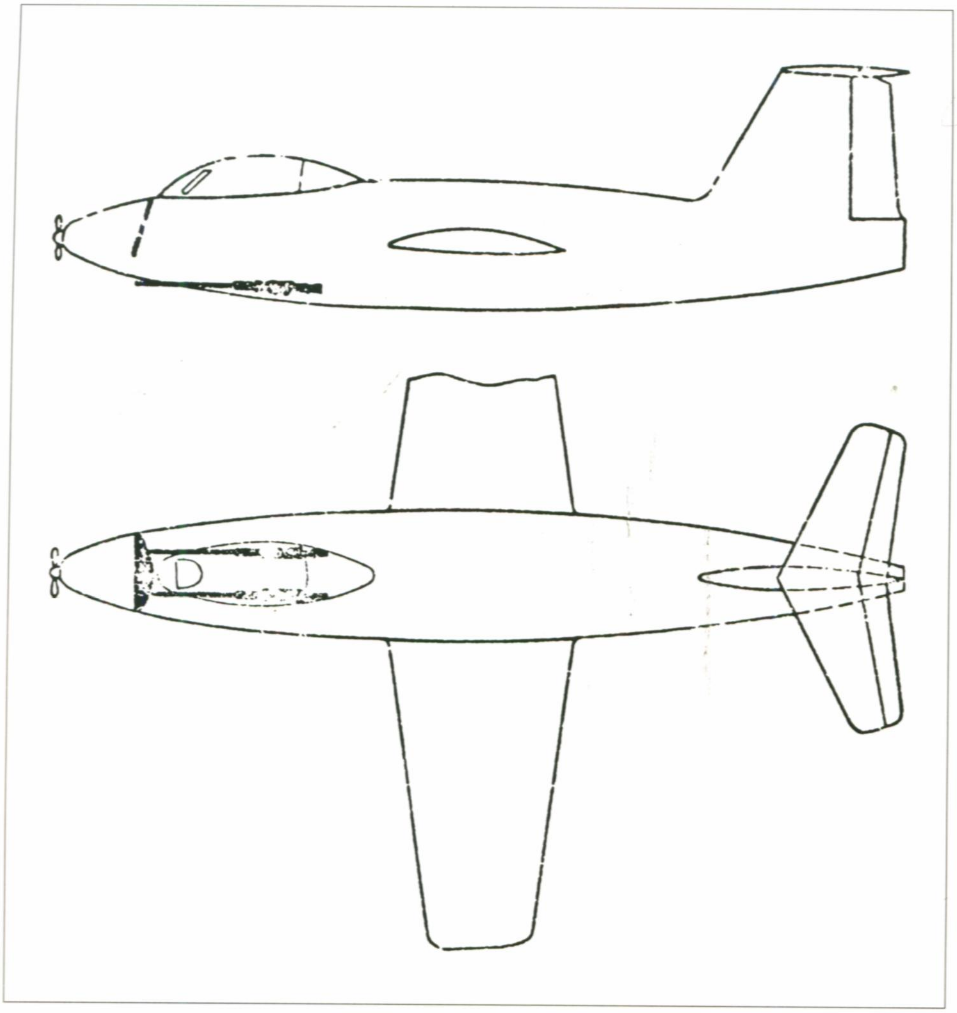
The armament was to comprise two 23-mm (.90 calibre) cannons. The fighter was intended for the air defence of large industrial facilities and military bases. The prototype was to be submitted for flight testing on 1st November 1946.

By that time the design bureau led by Leonid S. Dooshkin, which was part of the NII-1 research establishment working within the NKAP framework, had developed a new twin-chamber liquid-fuel rocket motor – the RD-2M3V which featured fuel pumps and ran on kerosene and nitric acid. The thrust of the bigger chamber was 1,100 kgp (2,425 lbst), the smaller one yielded 300 kgp (660 lbst). This enabled the fighter to take off and climb at maximum thrust with both chambers running; then the pilot could shut down the bigger chamber, locating the target and attacking it with only the smaller chamber working. This afforded a considerable fuel saving and increased the endurance. It was virtually impossible to throttle back a liquid-fuel rocket motor in any other way. During the state acceptance trials of the RD-2M3V conducted in May 1945, the aggregate maximum take-off thrust obtained with both chambers running was 1,500 kgp (3,310 lbst), the nominal thrust being 1,250 kgp (2,760 lbst). The specific thrust per 1 kg of fuel with both chambers ignited was 200 kgp (440 lbst); the declared weight of the fully dressed engine was 224 kg (494 lb). Plant No.165 was tasked with manufacturing 30 sets of this engine for the experimental interceptors which were under development at the Mikoyan and Lavochkin OKBs, as well as for the experimental aircraft that were being developed by NII-1.

Albeit the official directive on the rocket-propelled interceptors was issued in 1946, OKB-155 had begun the first studies on this subject as early as September 1945. In their



An artist's impression of the *izdeliye* Zh (I-270) interceptor from the project documents. It is accurate enough, except for the outsize cockpit canopy which makes the machine look smaller than it was.



This drawing illustrates the armament placement and armour protection of the *izdeliye* Zh. The stabiliser sweepback is rather exaggerated (compare to the three-view on the right).

project the designers tried to eliminate or alleviate the drawbacks of the previous Soviet rocket-powered aircraft and of the captured German aircraft that had been examined. These deficiencies included:

- difficulties in piloting tailless fighters (the Messerschmitt Me 163) associated with the absence of means of flight automation and with the low-aspect-ratio wings;
- the influence of the wing downwash on the empennage at transonic flight speeds;
- the lack of possibility to control the engine thrust.

The initial project of the aircraft, known under the in-house designation '*izdeliye* Zh' (Zh is the eighth letter of the Cyrillic alphabet), envisaged the use of wings swept back 20°; however, TsAGI specialists, having attempted to adapt their calculations to the basic data supplied by OKB-155, proved unable to produce an encouraging conclusion on this design. Faced with this situation, the designers were compelled to revise the project in March 1946 and use unswept wings with a thickness/chord ratio of 9% instead. However, TsAGI failed to confirm the possibility of obtaining the required performance on an aircraft fitted with these wings, either. In April the project was revised for the second time, incorporating wings with a thickness/chord ratio of 12%. The designers' further work was seriously hampered by difficulties in obtaining the necessary structural strength and aerodynamic characteristics of the wings. The final recommendations on the wing shape and airfoil were endorsed as late as 8th August. As already noted in previous chapters, by early 1946 TsAGI specialists had not yet accumulated sufficient experience in calculating high-speed wings and displayed utter caution in issuing recommendations to design bureaux, which eventually not only contributed to delays in the work on the 'Zh' project but was instrumental in halting the work on a number of other promising projects.

By the end of March 1946 the designers had largely completed the work on defining the aircraft's general arrangement and started issuing detail drawings for the construction of a full-scale mock-up. In April V. M. Belyayev was appointed the aircraft's project engineer. Following recommendations from TsAGI, the original 'blunt' nose section of the fuselage was slightly extended to give it a more streamlined shape. On 17th May GK NII VVS representatives inspected the mock-up and made some critical comments. These were taken into account and the mock-up was modified accordingly.

The ADP of *izdeliye* Zh was completed by the end of May. Interestingly, the weight of the liquid-fuel rocket motor was very much higher than the figure declared initially, amounting to 340 kg (750 lb). The table on page 77 lists the design dimensions and design performance of the 'Zh' interceptor as per the advanced development project.

The explanatory notes to the advanced development project, dated 30th May 1946, stated:

'If the wings' influence on the horizontal tail is reduced, one can assume that characteristics of (aerodynamic) moment will remain satisfactory up to Mach 0.9. For this purpose the aircraft's horizontal tail has been raised relative to the wings to a height equal to 1.2 of the mean aerodynamic chord.

As soon as wind tunnel tests make it possible to start projecting swept-back wings, the current wings on this aircraft will be replaced by the swept ones; this, in combination with the increased thrust of the Dooshkin-designed engine, will make it possible to increase considerably the level flight speed and even to exceed 1,100 km/h' (683 mph).

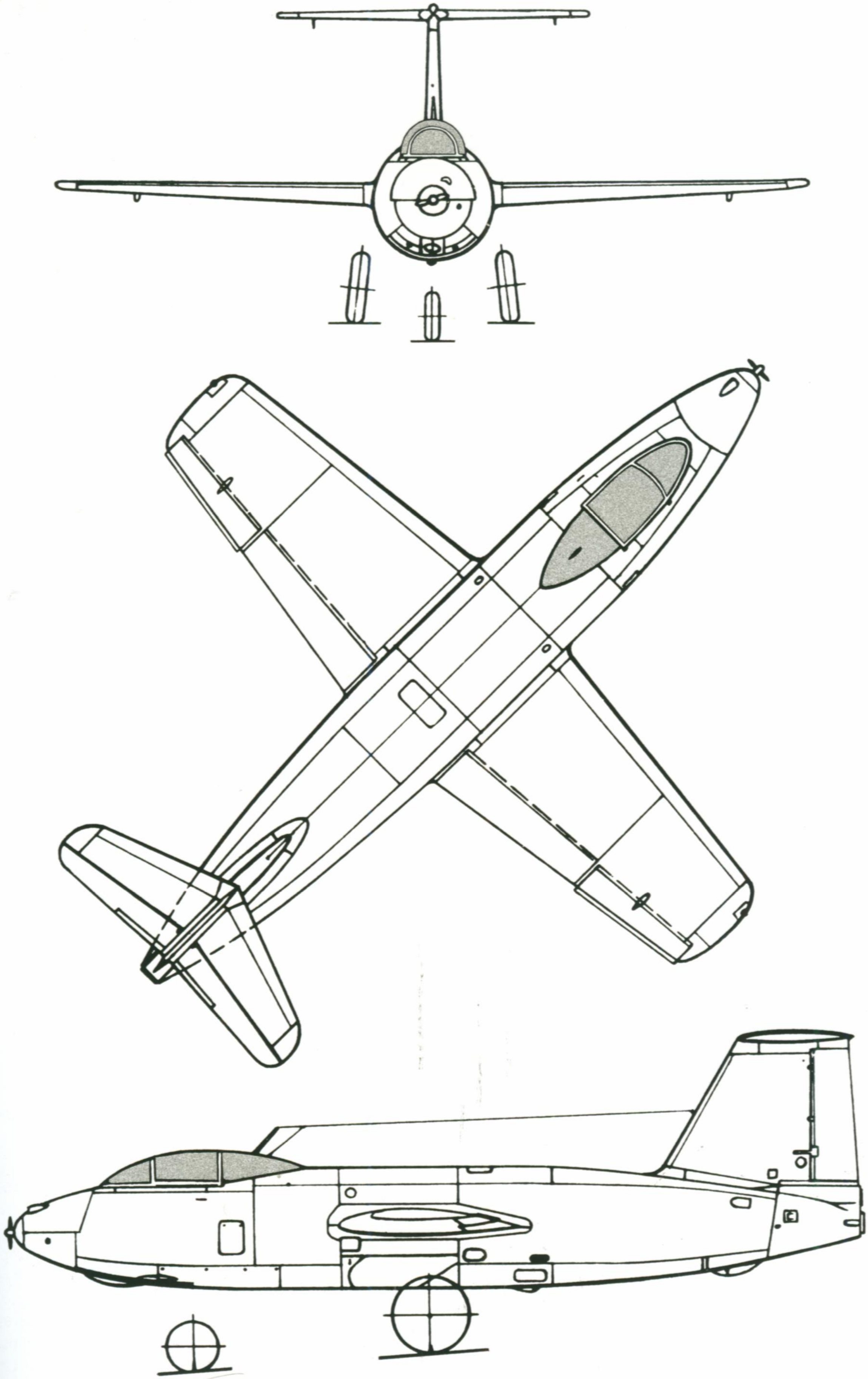
Indeed, the plans of NII-1 for 1946 envisaged boosting the thrust of the RD-2M3V rocket motor to 2,000 kgp (4,410 lbst). In addition, to ensure the pilot's survival in an emergency, the machine was to be equipped with an ejection seat.

In an effort to increase the endurance of the rocket-propelled interceptor, on 18th April 1946 the Ministry of Aircraft Industry issued order No.222 which tasked the chief of NII-1 and Chief Designer L. S. Dooshkin with developing, building and submitting for state bench tests in November 1946 an RD-2M3V rocket motor with a service life of one hour. Moreover, two such engines with the mentioned service life were to be supplied to OKB-155 as early as 1st July 1947.

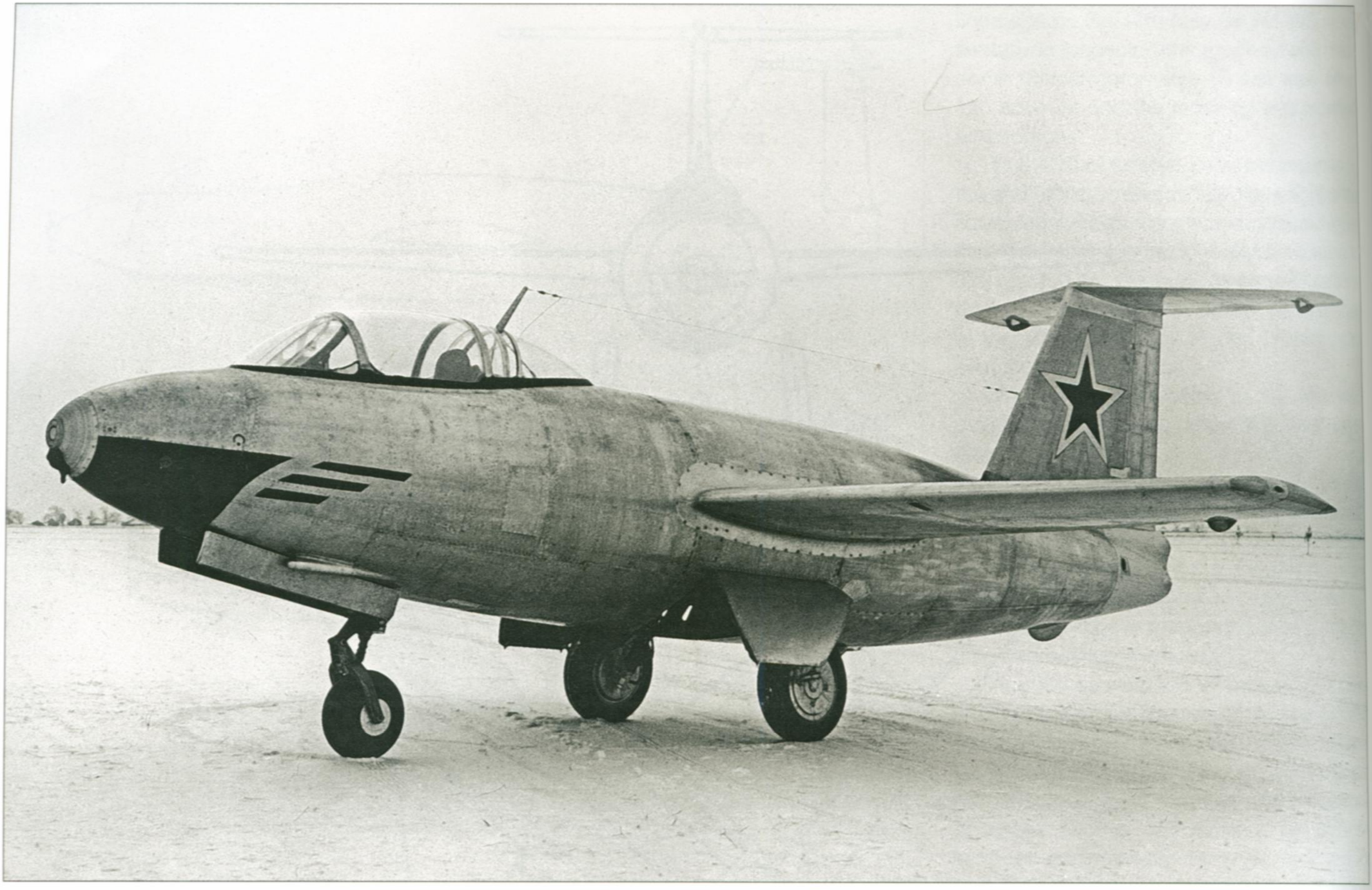
The design staff of OKB-155 envisaged supplementing the aircraft's armament in the future by rocket projectiles. For this purpose they intended to fit the aircraft with two four-tube rocket launchers.

On 15th May 1946 OKB-155 approved a schedule for projecting and manufacturing the *izdeliye* Zh; the aircraft had by then received the official designation I-270 (I = *istrebitel'* – fighter). In accordance with this schedule the roll-out of the first prototype was to take place on 20th October 1946.

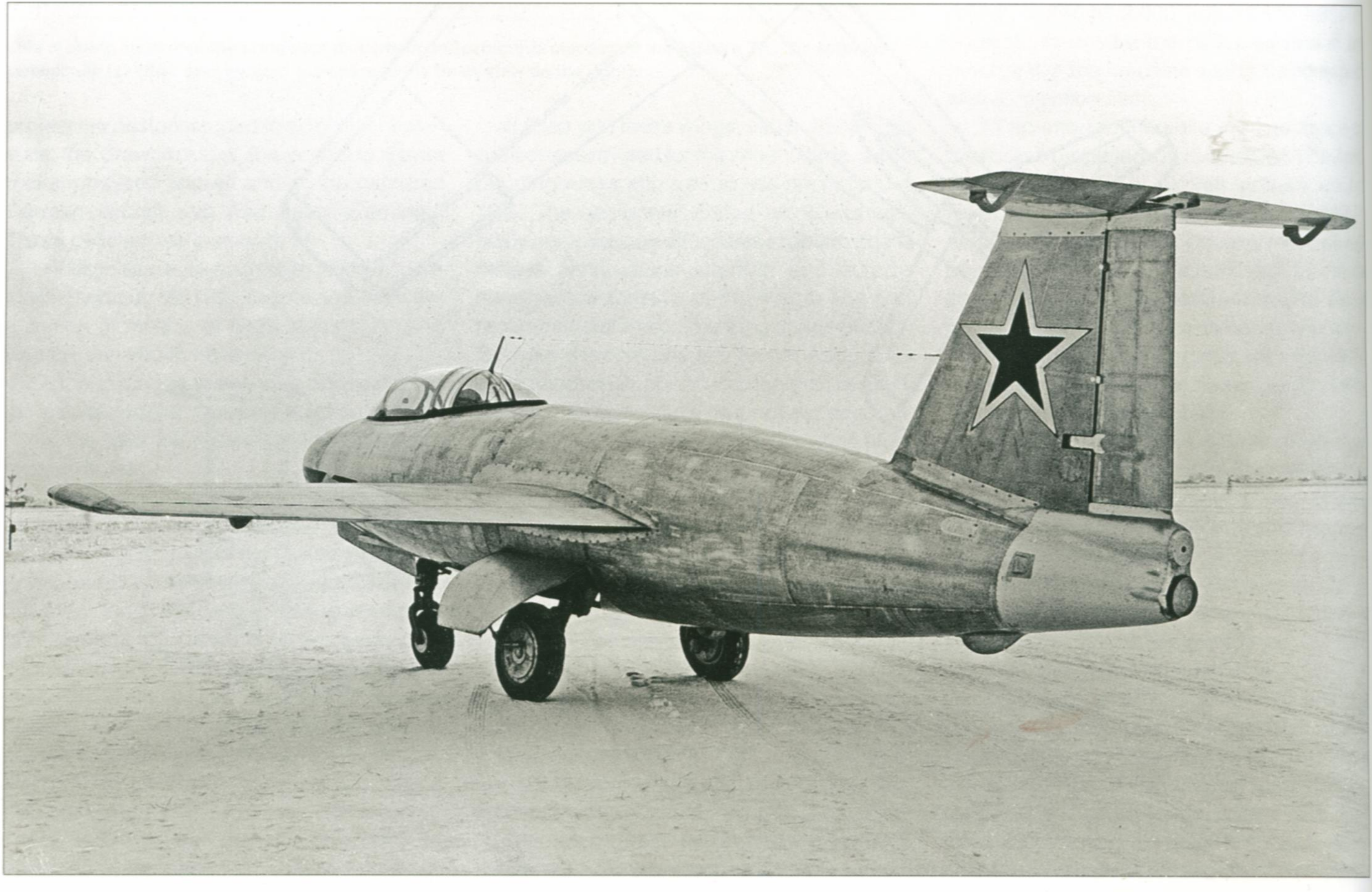
The first set of detail drawings of the aircraft was produced in the course of a mere three months and 10 days (between March and July); however, due to repeated revisions

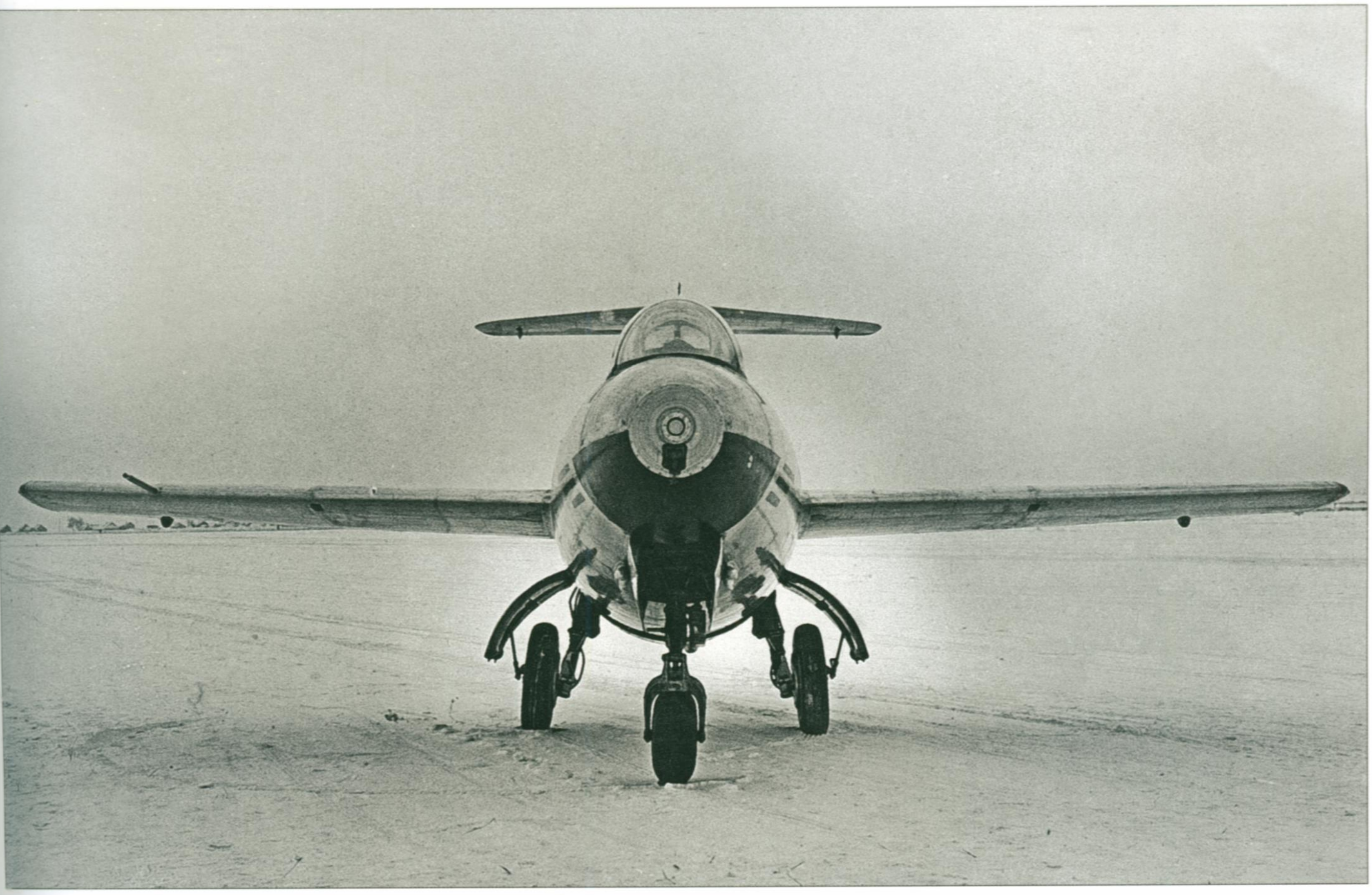


A three-view drawing of the *izdeliye* Zh (I-270). Note the narrow wheel track and the very slight sweepback on the horizontal tail.

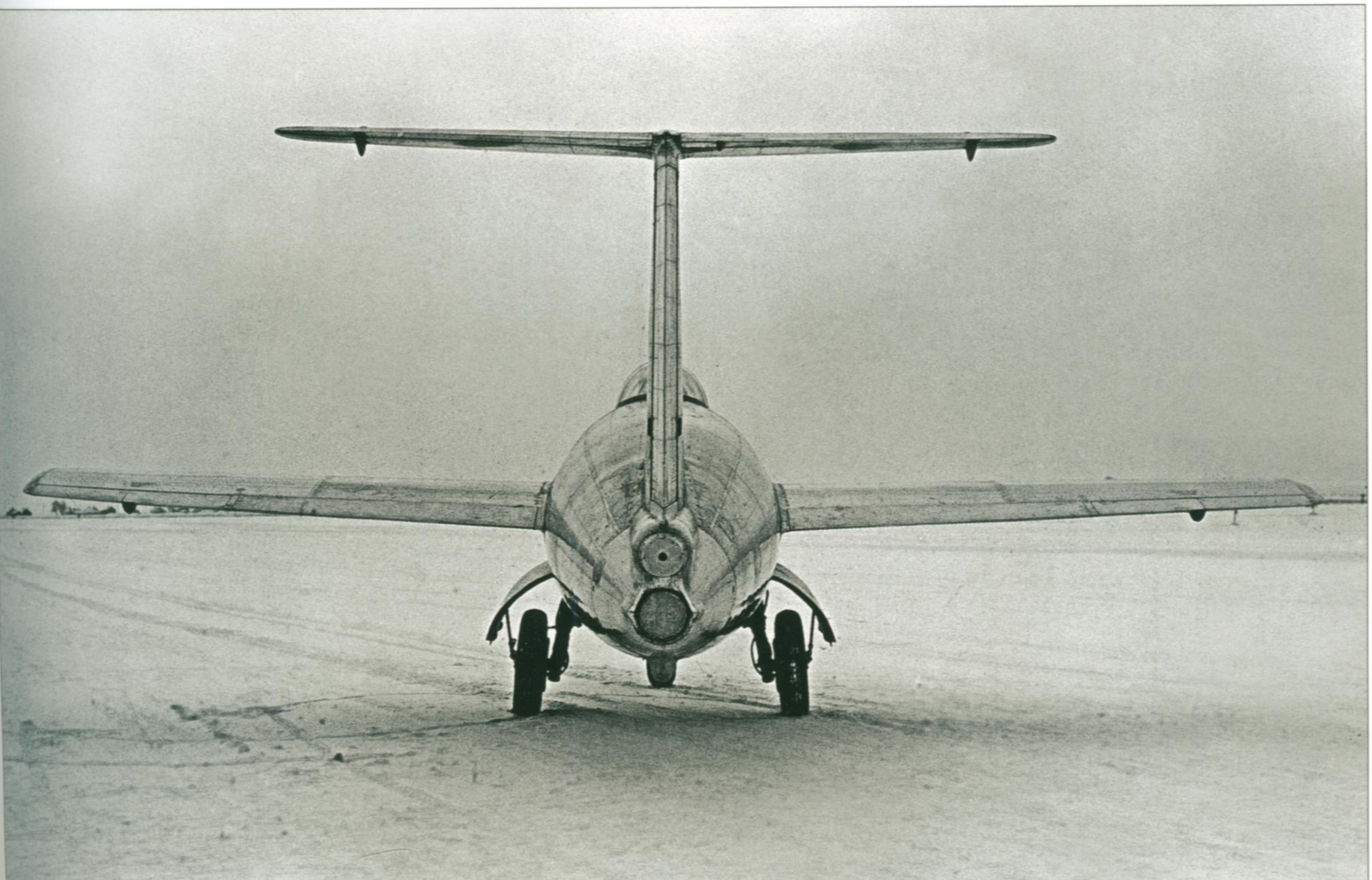


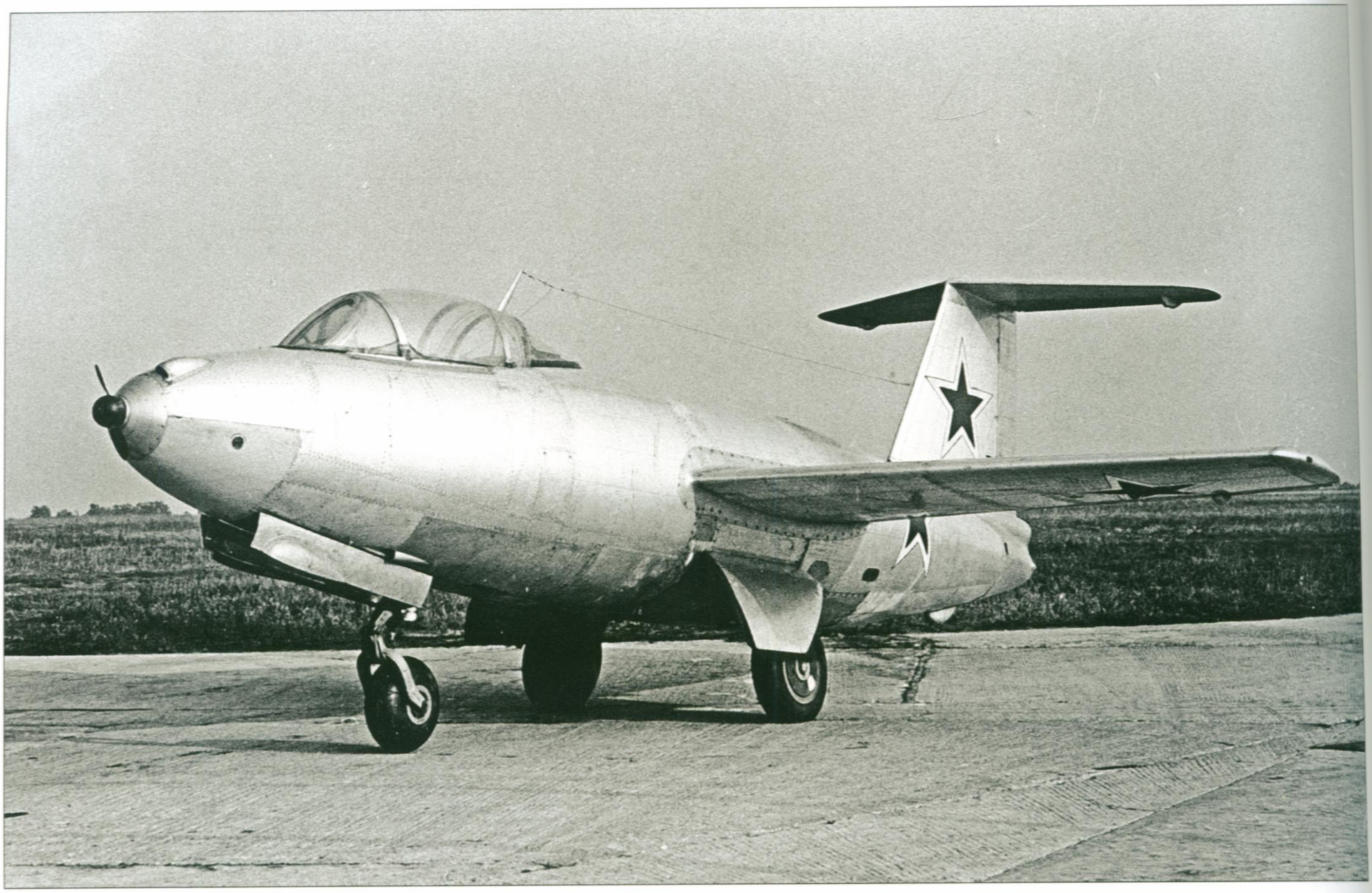
Above and below: The first prototype I-270 (aka Zh-1). Note the absence of the generator drive vane on the nose and of the star insignia on the fuselage. No rocket motor was fitted initially, which is why the nozzles are blanked off here. The elevators have prominent mass balances.



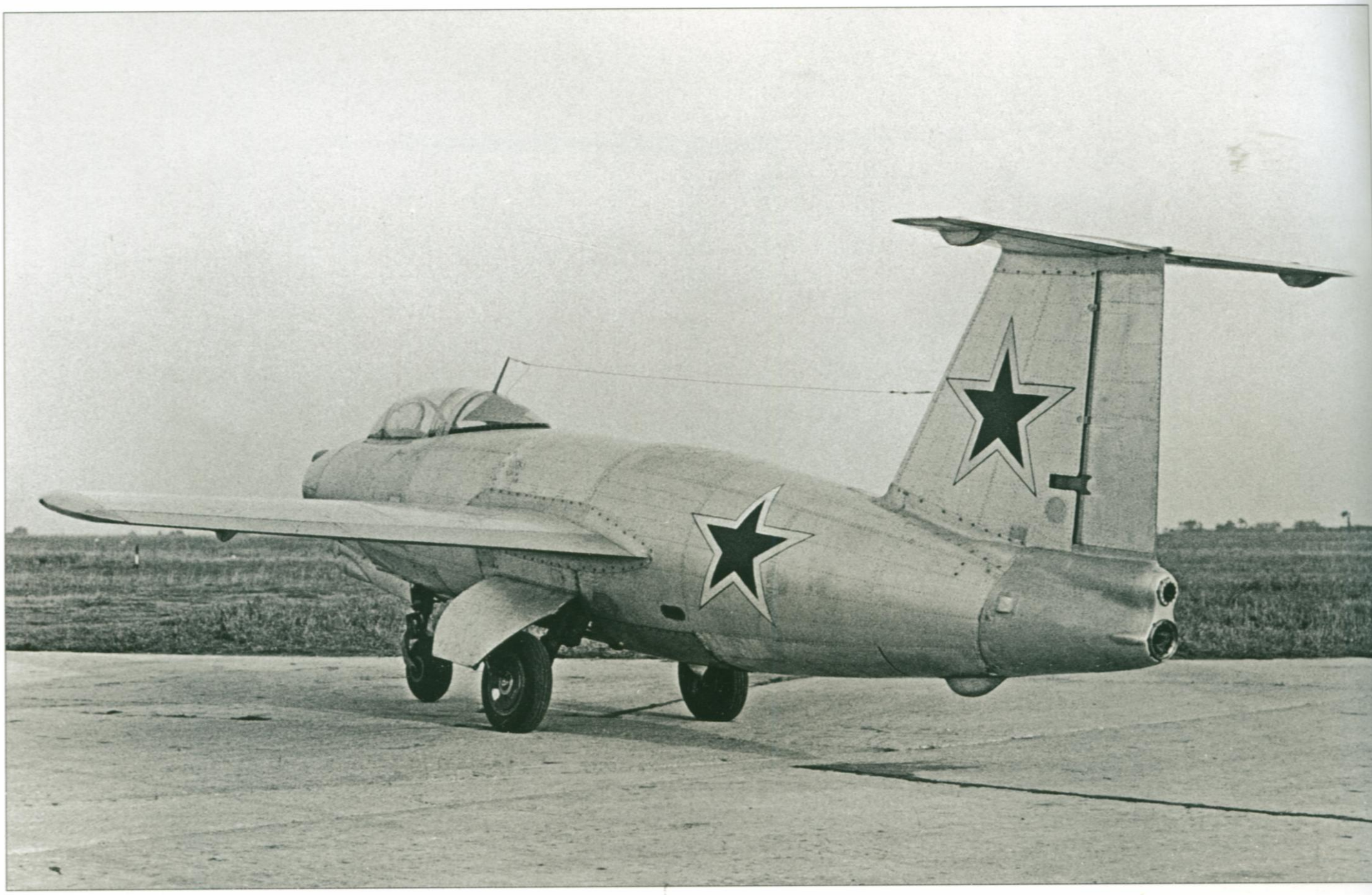


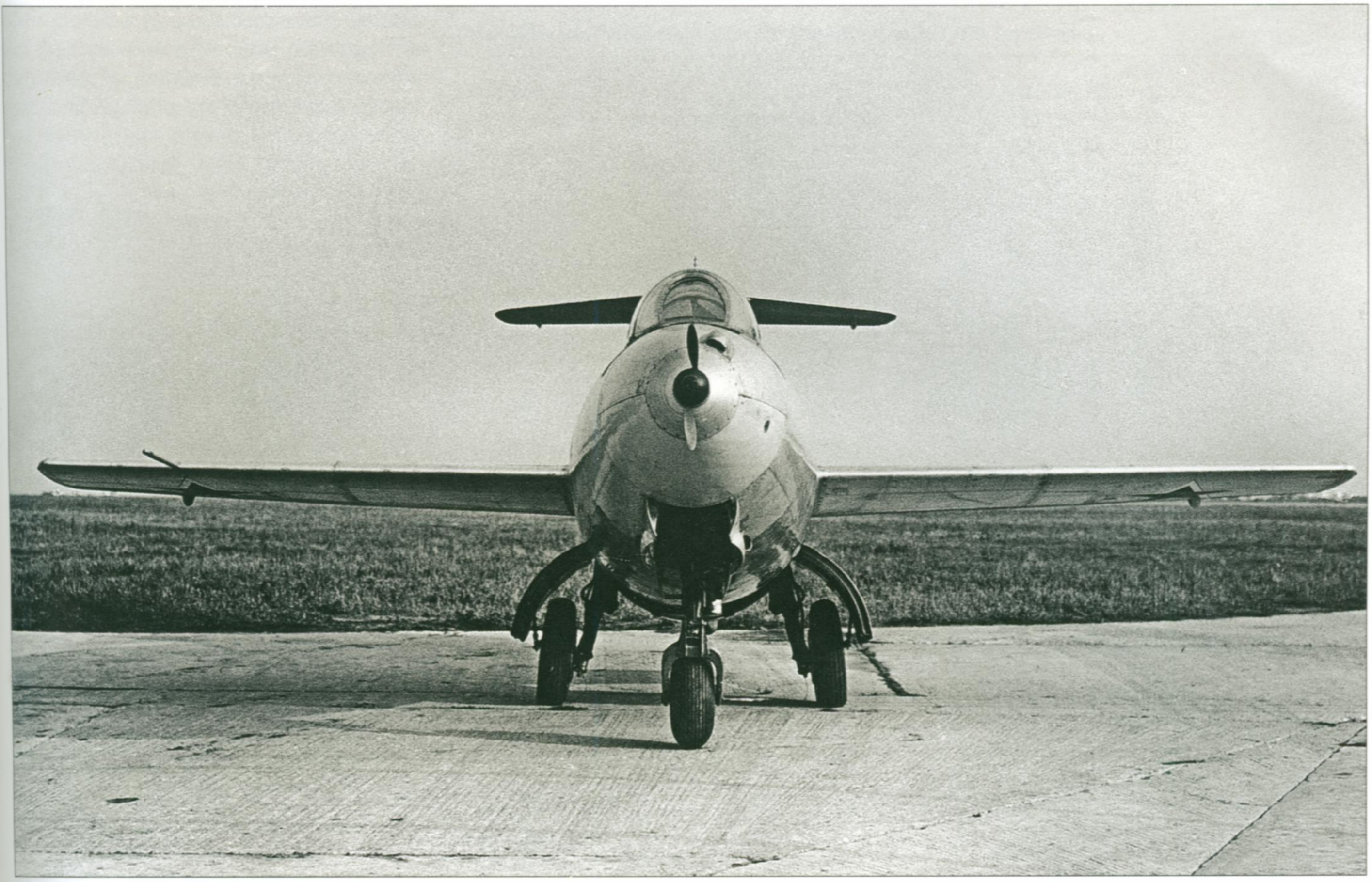
Above and below: Front and rear views of the first prototype, showing the slight wing dihedral and the linkages connecting the mainwheel axles with the wheel well doors. Note the curved windshield and the equal size of the rocket motor nozzles.



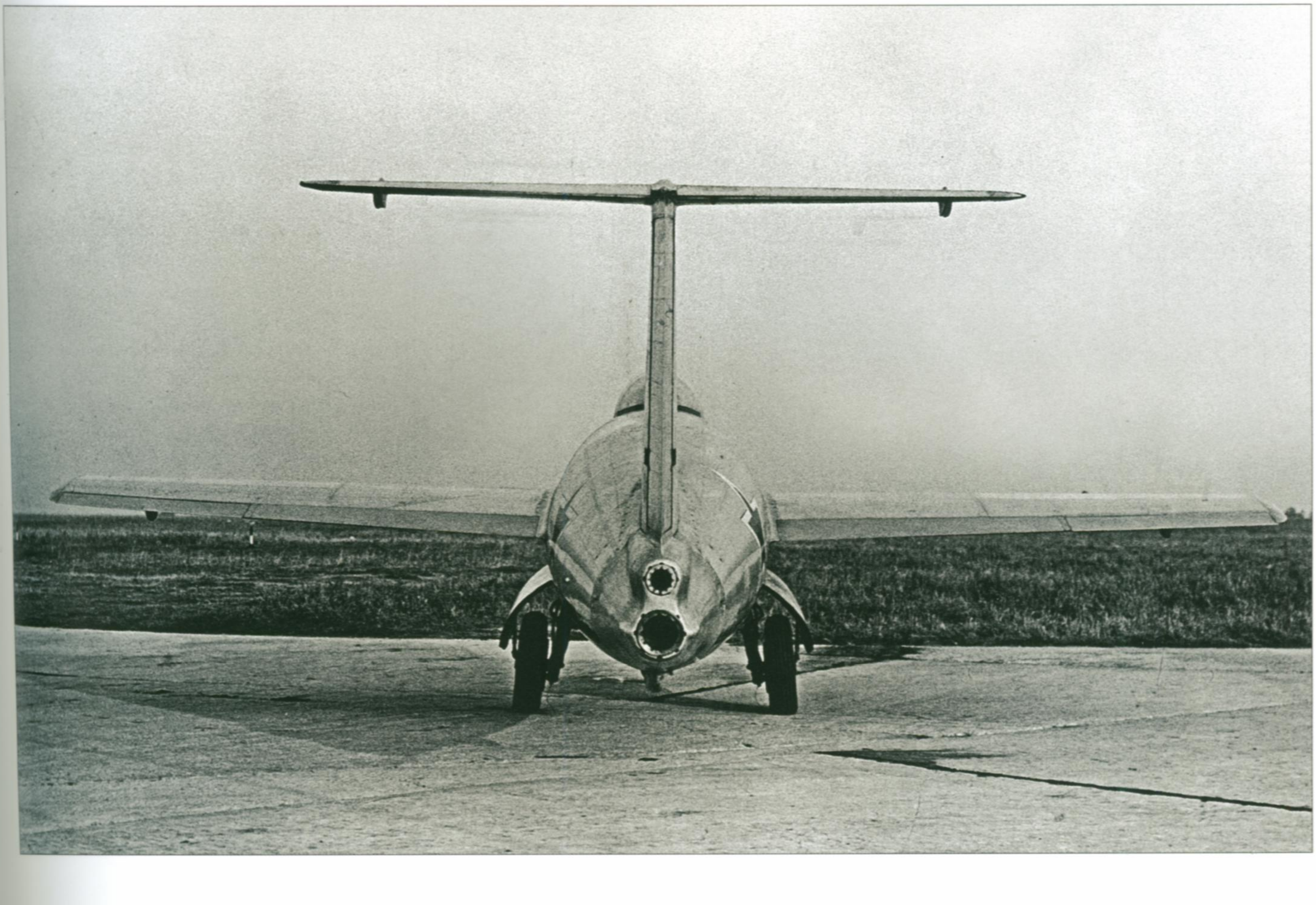


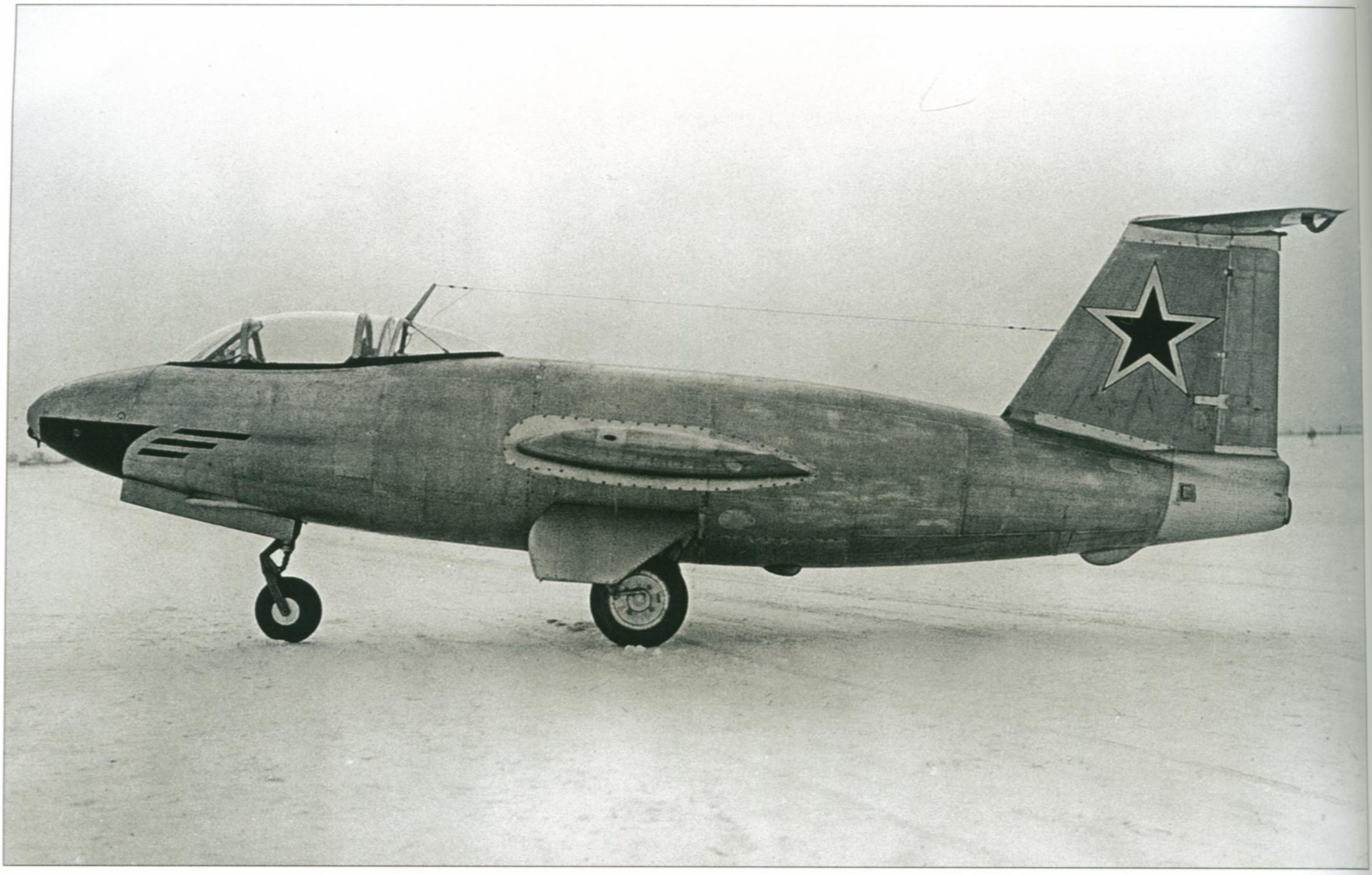
Above and below: Apart from the paintwork, the second prototype I-270 (Zh-2) differed from the first one in having the generator drive vane on the nose, an offset air scoop aft of it, a revised canopy with a flat bulletproof windscreen, bulged nose gear doors and smaller faired elevator mass balances.



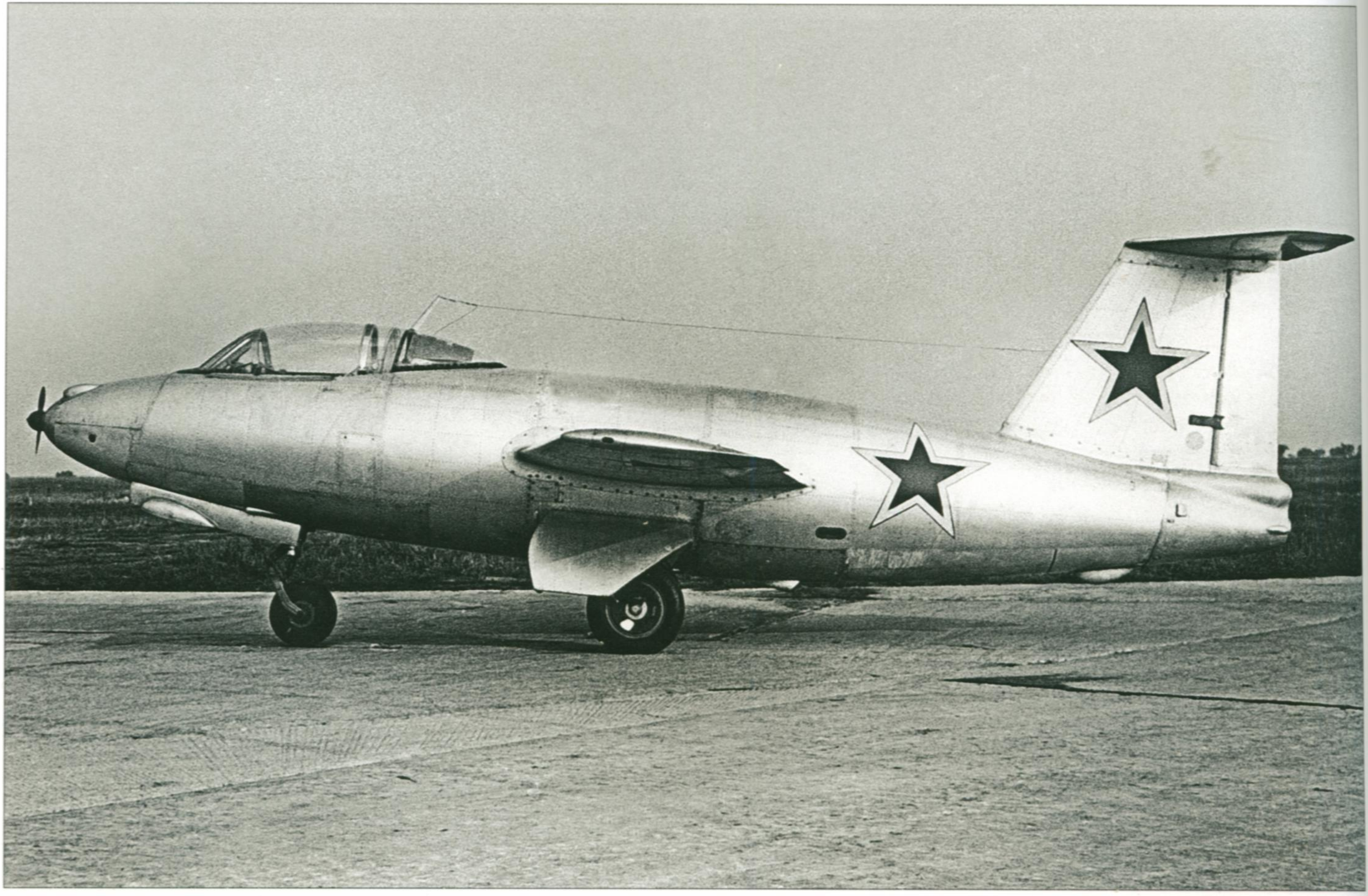


Above and below: Front and rear views of the second prototype I-270. Note the canted position of the mainwheels when extended. The different diameter of the rocket motor's take-off (lower) and cruise (upper) chambers is obvious.





These side views of the Zh-1 (above) and the Zh-2 illustrate the I-270's short landing gear wheelbase and pronounced nose-up attitude on the ground, as well as the stabiliser sweepback. Again, note the difference in the canopy design, as well as in the position of some access panels.



of the project it was not before 2nd October that the final version of detail drawings was completed. By that time assembly of the forward fuselage with the pressurised cockpit was nearing completion (the pressurised cockpit was to be tested in a thermo-vacuum chamber); static tests of the tail unit were also started. A considerable slackening in the tempo of work on the *izdeliye* Zh was also due to a decision to send the chiefs of the main workshops to plant No.1 in Kuibyshev (now renamed back to Samara) where they were to assist in manufacturing the initial batch of MiG-9 twin-turbojet fighters. For this reason it proved impossible to submit the aircraft for flight testing by the stipulated time. In addition, the factories subordinated to MAP's 5th and 8th Main Directorates had failed to deliver the necessary instruments on schedule.

Of the three prototypes of the I-270 that had been laid down, only two were completed. It turned out that the weight of the empty airframe had risen to 1,893 kg (4,174 lb) as compared to the design figure of 1,564 kg (3,449 lb). The first prototype (*izdeliye* Zh-1) was rolled out from the assembly shop on 28th December 1946. A. F. Turchkov was appointed project engineer for manufacturer's tests, with V. N. Yuganov as project test pilot. The delivery of a flight-cleared rocket motor was being delayed, so the aircraft was temporarily fitted with a mock-up engine that had been received on 21st October. For this reason full-scale testing could not begin right away, and the test programme was divided into two stages.

During the first, 'unpowered' stage the aircraft was towed by a production Tu-2 bomber (c/n 1041). For this purpose the weight of the prototype fighter was reduced: the I-270 was stripped of all items that were not necessary at that stage, such as the mock-up rocket motor, fuel tanks, fuel lines and armament. The towed flights began on 3rd February 1947 when the I-270 performed a 13-minute maiden flight with Yuganov at the controls; the glider tug was flown by test pilot Igor' I. Shelest. The test flight was preceded by preparations on 11th and 13th January, when the prototype interceptor was towed on the ground and released from the tow cable after reaching a certain speed and making a hop to a height of 1.5-2 m (5-6 ft). On 3rd February, shortly before the first towed flight, Yuganov performed a training flight in a Yak-9 fighter which was also towed behind a Tu-2 as a glider; to emulate the longitudinal and lateral stability characteristics of the *izdeliye* Zh, the fighter was loaded with lead slabs.

During the towed flights the interceptor prototype cast off after both machines had climbed to 5,000-7,000 m (16,400-22,960 ft); thereupon the I-270 performed a free flight and landed in glider mode. Its maximum air-

Dimensions and Performance of the 'Zh' Interceptor (as per ADP Documents)

Length overall	8.915 m (29 ft 3 in)
Fuselage length (less nose-mounted generator drive vane)	8.77 m (28 ft 9¼ in)
Fuselage diameter	1.25 m (4 ft 1¼ in)
Height on ground	2.8 m (9 ft 2¼ in)
Wing span	7.75 m (25 ft 5 in)*
Wing chord:	
at tip	1.06 m (3 ft 5¾ in)
at the aircraft's axis	2.13 m (7 ft 0 in)
Wing area, m² (sq ft)	12 (129)
Horizontal tail span	3.18 m (10 ft 5 in)
Horizontal tail area, m² (sq ft)	2.5 (26.9)
Vertical tail area, m² (sq ft)	2.5 (26.9)
Landing gear track	1.6 m (5 ft 3 in)
Landing gear wheelbase	2.415 m (7 ft 11 in)
Empty weight, kg (lb)	1,564 (3,449)
All-up weight, kg (lb):	
normal	2,556 (5,636)
maximum	4,121 (9,087)
Fuel load, kg (lb)	2,120 (4,675)/2,150 (4,740)†
Wing loading, kg/m² (lb/sq ft)	344 (70.46)
Maximum speed, km/h (mph):	
at sea level	1,000 (621) (Mach 0.815)
at 5,000 m (16,400 ft)	990 (615) (Mach 0.86)
at 10,000 m (32,800 ft)	928 (577) (Mach 0.87)
at 11,000 m (36,080 ft)	925 (575) (Mach 0.87)
at 15,000 m (49,200 ft)	936 (582) (Mach 0.88)
Landing speed, km/h (mph):	
flaps deployed	137 (85)
flaps retracted	156.5 (97)
Time to altitude, seconds:	
to 5,000 m	88.5
to 10,000 m	144.0
to 11,000 m	150.4
to 15,000 m	181.25
Service ceiling, m (ft)	17,970 (58,940)/17,000 (55,760)†
Maximum endurance at 15,000 m (49,200 ft), minutes:	
with both combustion chambers ignited	4.14
with one combustion chamber ignited	4.89
Take-off run, m (ft)	895 (2,937)
Landing run, m (ft)	493 (1,618)
	956 (3,137)‡
Armament	
cannon	2 x NS-23 (115P)
ammunition, rounds	2 x 40 (50)‡

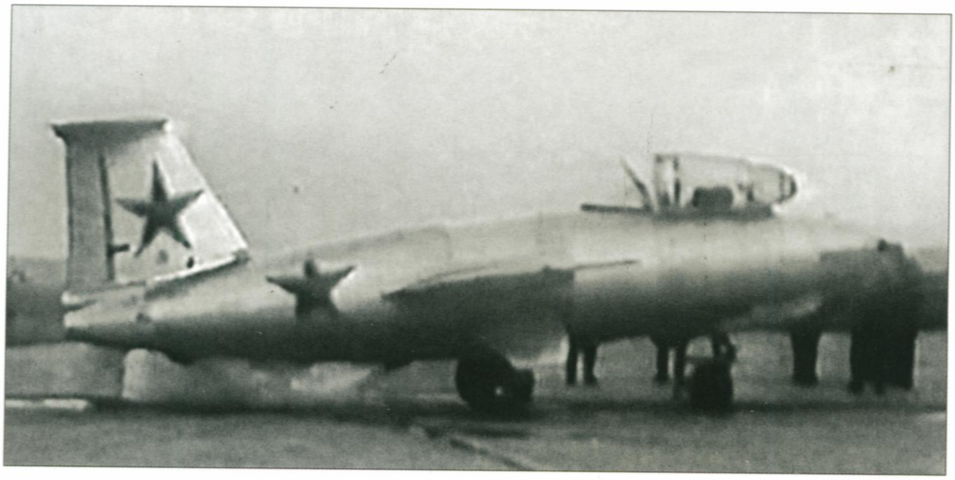
Notes
* The projected version with swept wings had the same span
† The second figure comes from the statistical card
‡ According to different documents

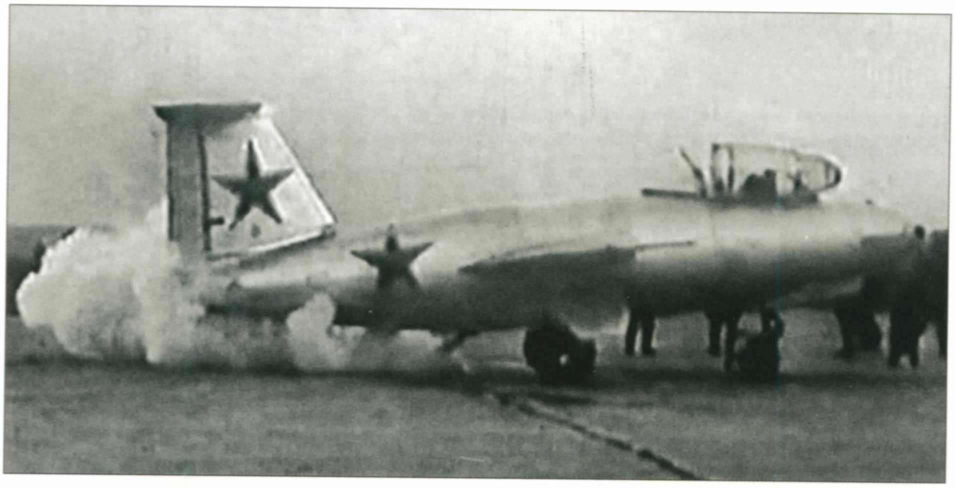
Design Thrust Rating of the RD-2M3V Rocket Motor (own weight 340 kg/750 lb)

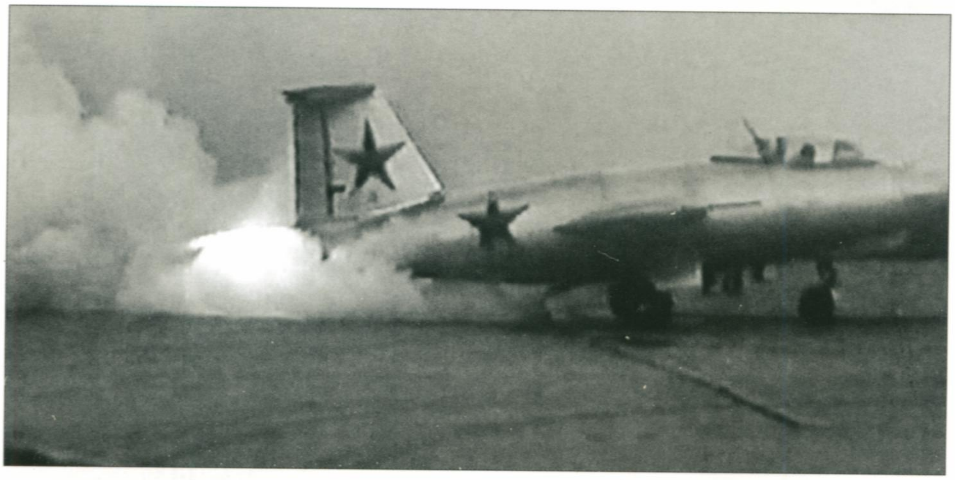
Thrust, kg (lb)	Flight altitude, m (ft)	Flight speed, km/h (mph)	Specific fuel consumption, kg/sec (lb/sec)
1,450 (3,197)	0	1,000 (621)	7.67 (16.91)
1,535 (3,385)	5,000 (16,400)	990 (615)	7.49 (16.51)
1,580 (3,484)	10,000 (32,800)	928 (577)	7.39 (16.29)
1,590 (3,506)	15,000 (49,200)	936 (582)	7.27 (16.03)

Time of Operation of the RD-2M3V at Different Altitudes at Maximum Design Speed

Time of operation, sec.	Flight altitude, m (ft)	Max speed, km/h (mph)
243	0	1,000 (621)
247	5,000 (16,400)	990 (615)
248	10,000 (32,800)	928 (577)
249	15,000 (49,200)	936 (582)







Top: Preparations for a take-off of the second prototype I-270 are in progress. Note the cockpit canopy hinged open to starboard.

Centre: A cloud of acid fumes billows from the rocket motor nozzle and…

Above: …ignition! A sheet of flame spews out as the ground personnel retreats to a safe distance.

speed in free flight reached 600 km/h (373 mph), and the minimum speed was 220 km/h (137 mph). The first stage of the testing was completed on 25th June; it allowed the designers to assess the aircraft's stability, handling and manoeuvrability, as well as to record the trim curves. A total of 11 towed flights were performed.

During the first post-war years, when the Soviet leaders finally understood that the country was lagging behind in the field of the development of jet aircraft, which was fraught with a serious imbalance of forces on the world arena, exceedingly tough measures were taken to ensure the speediest possible introduction of jet engines and the first jet aircraft into series production. Orders to this effect were issued both by the Government (the Council of People's Commissars, later the Council of Ministers) and personally by I. V. Stalin. Failure to comply with these often entailed severe penalties, everybody was anxious to avoid being swept away by yet another wave of reprisals.

During that controversial period much importance was attached to political propaganda, especially inside the country. Among other things, a special role was played by the traditional air events which were held in the USSR on Aviation Day. Not only were these shows a festive occasion for the Soviet people; they were called upon to show the whole world the power of the Soviet Aviation. Hear ye! Fear ye! The air shows that had been held almost annually in the pre-war years were not held during the war; the tradition was revived only in 1946. The country's leaders wanted to see for themselves the post-war achievements of the Soviet aircraft industry; therefore both the top management of MAP and the Air Force Command regarded the preparation of the annual air events as a matter of utmost responsibility. In early 1947 MAP issued an order 'On the preparation of aircraft for participation in the Air Display to be held on 18th August 1947' which included the following passage:

'For the purpose of timely preparation of aircraft for participation in the air display to be held on 18th August of this year, I HEREBY ORDER the following:

1. Chief Designer and Director of plant No.155 Comrade Mikoyan shall:

a) complete by 20 July of this year the flight development […] of the 'Zh' interceptor with a twin-chamber rocket motor designed by Dooshkin and study the options of this aircraft either taking off from Tushino airfield or being released from a carrier aircraft above the airfield…'

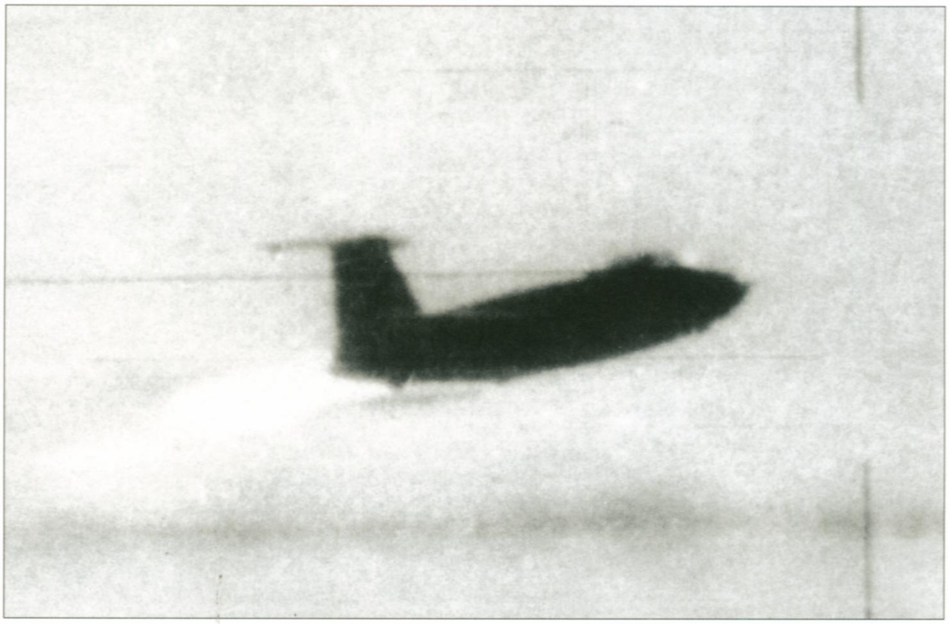
On 8th May a flight-cleared example of the RD-2M3V engine was installed in the second prototype I-270 (*izdeliye* Zh-2). N. I. Kovunovskiy was appointed project engineer for the engine, with A. I. Lukashov as mechanic. However, on 16th July, when ground runs of the engine were almost complete, the smaller chamber exploded, inflicting damage to the aft fuselage. The machine had to undergo repairs which lasted until 2nd August.

On 26th August Lieutenant-Colonel A. K. Pakhomov, a GK NII VVS test pilot who had joined the test programme to relieve Yuganov (the latter had been taken ill), performed two taxi runs and one short hop in the 'Zh-2'. The first unassisted take-off of the interceptor prototype took place in the evening of 2nd September. The take-off with the engine ignited proceeded normally, the aircraft climbed to 3,000 m (9,840 ft), after which, in accordance with the test mission, the pilot started a gliding descent for landing. However, he made a mistake in his calculations and, sweeping past the markers denoting the touch-down area, landed beyond the LII airfield, near the Moskva River. The pilot was unscathed but the interceptor suffered damage to the forward fuselage and was declared a total loss. Thus, the 7-minute first flight of the 'Zh-2' became its last flight.

In the meantime, the inoperative rocket motor on the first prototype, the 'Zh-1', was replaced by a functioning example, and on 14th August the machine was delivered to LII for flight testing. On 29th September, upon completion of the ground checks, V. N. Yuganov performed a taxi run, which was followed by the first flight in the morning of 4th October. Together with LII specialists, measurements were made of the flight trajectory and of the aircraft's speed and rate of climb in different flight modes. The flight was filmed by two Ascania cinetheodolites which were installed with a separation of 1,737 m (5,700 ft), shooting at 4 frames per second from the beginning of the take-off up to the moment of engine shutdown.

The prototype's unstick speed was 233 km/h (145 mph), the length of the take-off run and its duration were 697 m (2,287 ft) and 20 seconds respectively, the landing speed was 168 km/h 104 mph); the whole flight lasted 12 minutes. The bigger chamber of the engine was shut down after 130.5 seconds at an altitude of 4,450 m (14,600 ft), whereupon a speed of 615 km/h (382 mph) was attained at an altitude of 2,900 m (9,510 ft). However, as the machine approached the airfield, it transpired that the landing gear would not extend; all attempts to get the wheels down were to no avail. Choosing a suitable place, Yuganov made a perfect belly landing on a strip of a very limited length. The first prototype suffered only minor damage.

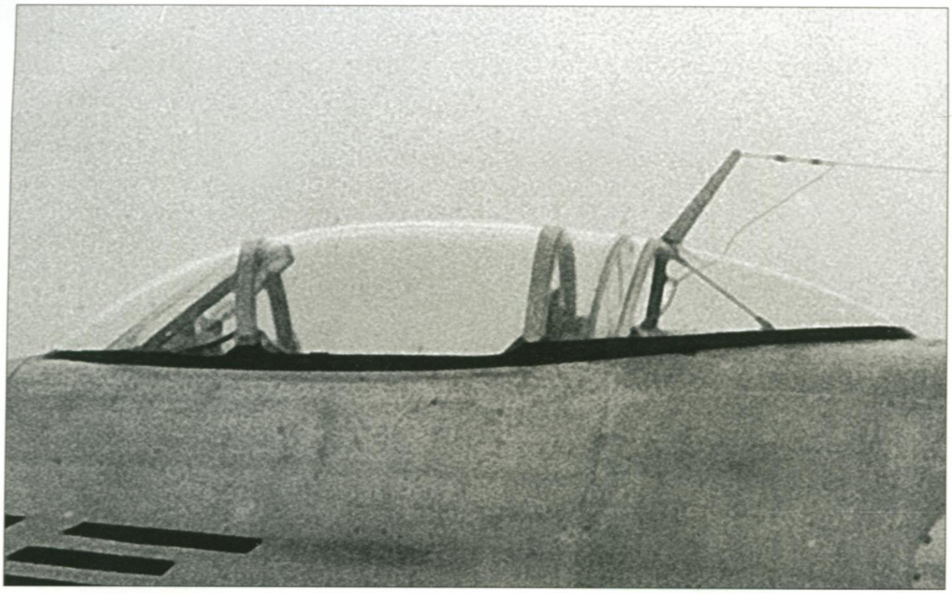
The reader must have noticed in the previous chapters of this book that nearly all Soviet designers dealing with rocket-propelled interceptors were confronted with the

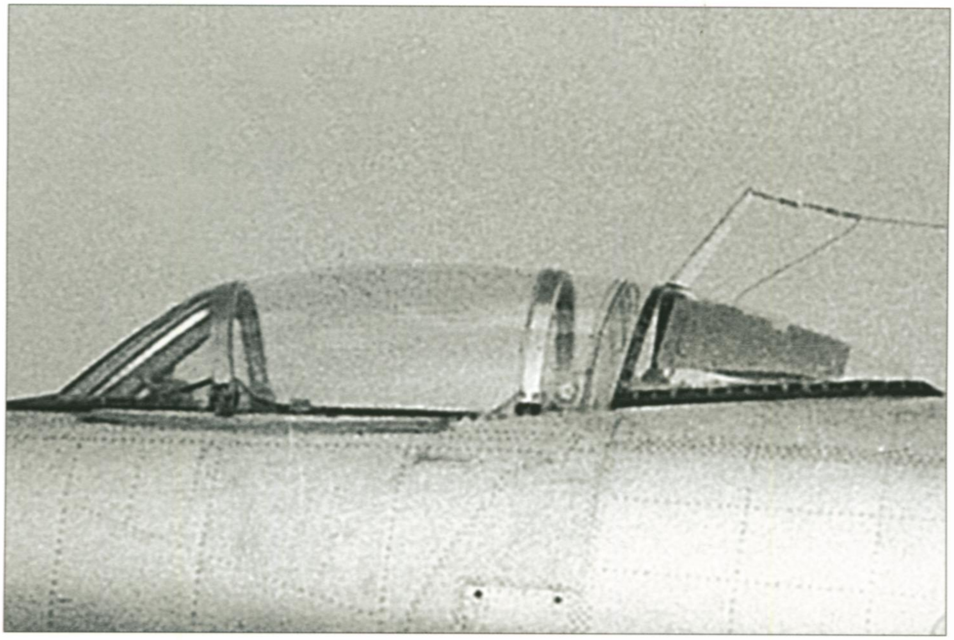


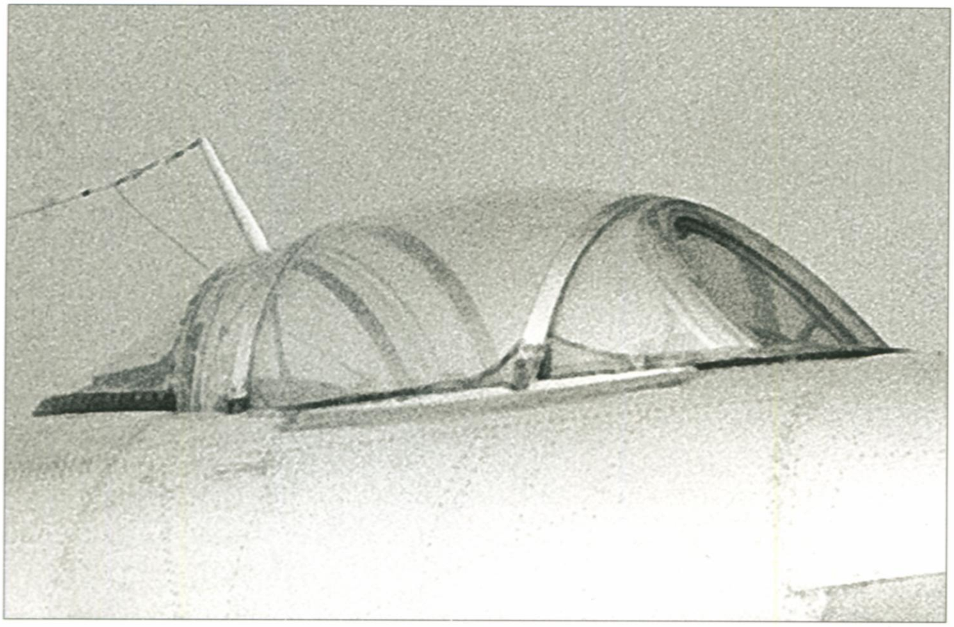
Top: An onlooker plugs his ears as the second prototype I-270 races down the runway at full power, spouting terrific flames. The roar must have been deafening!

Above: A still from a cine film showing the first prototype I-270 (Zh-1) as it makes a high-speed pass, dashing past like a 'bat outa hell' with a flaming wake behind it.

Right: Wheels down, the second prototype glides to a landing after its first flight – which, unfortunately was destined to be its last, ending in an overrun with irreparable damage to the aircraft as a result.







Left: Close-up of the first prototype I-270's cockpit canopy with its perfect teardrop shape. The forward/centre portion hinges open to starboard, while the rear portion (aft of the seat headrest) and the bulletproof windscreen are fixed.

Below left and bottom left: In contrast, the second prototype's cockpit canopy incorporated an optically flat windshield (to avoid distorting the view) and curved sidelights. Note the radio set aft of the seat headrest.

Right: Close-up of the second prototype's nosecone with the generator drive vane.

Far right, above and below: The first prototype's port wing.

Below right: The rear fuselage of the first prototype fitted with a dummy rocket motor and (far right) of the second prototype fitted with an operational rocket motor. Note the tail bumper.

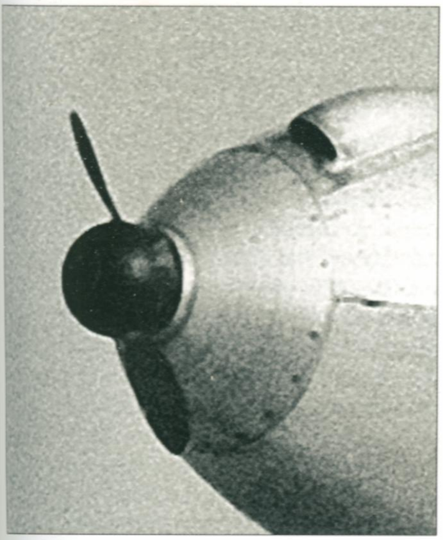
Bottom right: The tail unit of the first prototype with exposed elevator mass balances and (far right) of the second prototype with faired mass balances.

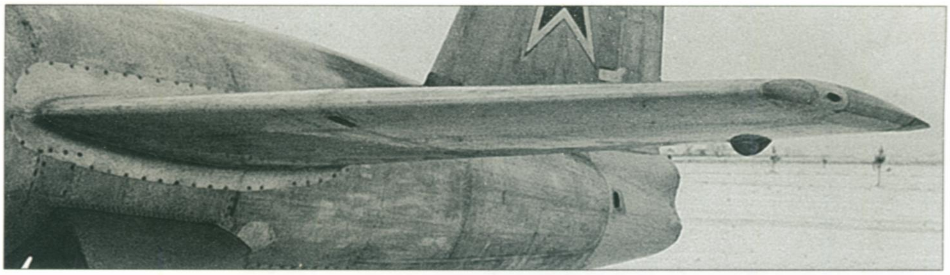
poor reliability of the liquid-fuel rocket motors. So were the designers of the I-270, too. On 21st October, after the completion of repairs, a ground run of the rocket motor ended in an explosion of the bigger chamber; the jet nozzle of the rocket motor was torn away. More repairs ensued; these were completed by 20th November.

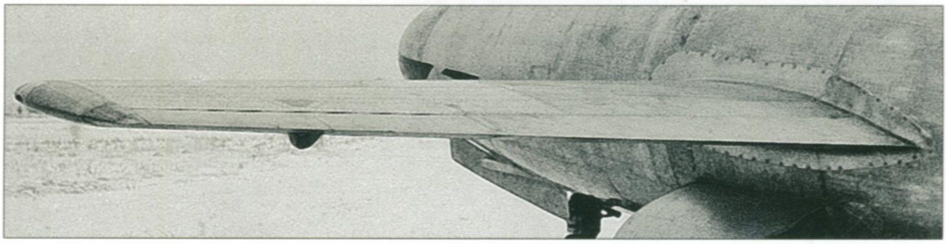
In January 1948 preparations were completed for yet another flight of the first prototype. However, the tests had to be suspended when it came to light that procedures for winter operation of a rocket motor using nitric acid had not been properly developed. After every flight the whole system had to be rinsed with water, which was, to put it mildly, difficult to do on a frosty day. Moreover, the weather conditions were not suitable for high-altitude flights. In consequence, after conferring with the engine's Chief Designer L. S. Dooshkin, OKB-155 Chief Designer A. I. Mikoyan gave instructions to mothball the aircraft until March.

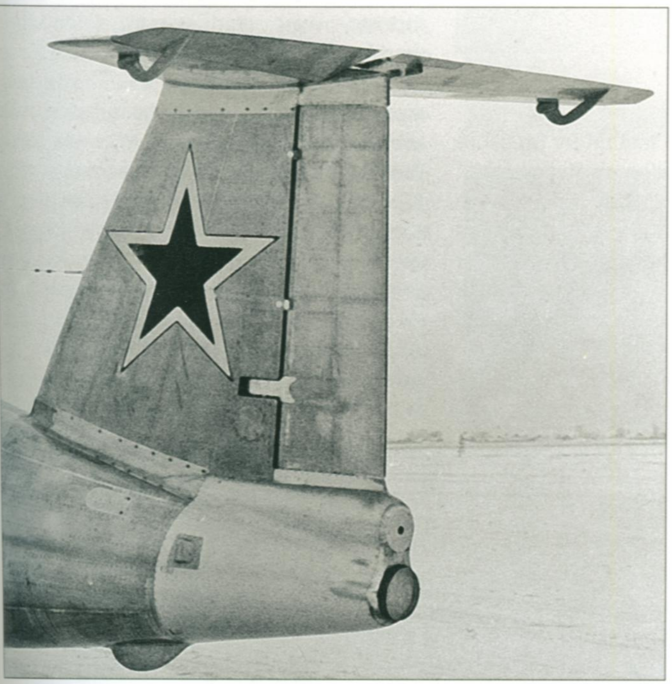
The military kept a close watch on the progress of the I-270 programme. From 1946 onwards the issues of ordering new military aircraft and of monitoring the construction and testing of prototype aircraft were the responsibility of the Air Force's Aviation Technology Committee (ATK VVS). Proceeding from the test results shown by the I-270, the specialists of this committee made the following conclusions in March 1948:

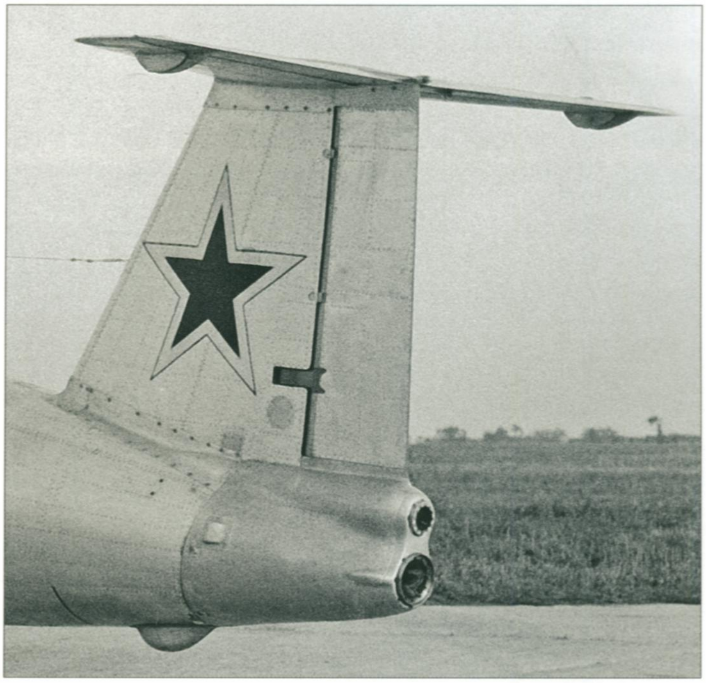
- steel parts are strongly affected by corrosion when subjected to nitric acid vapours, despite the protective coating;
- restarting the engine in flight is impossible due to the danger of explosion because of a possible accumulation of acid in the combustion chamber;
- it is difficult to calculate the landing approach with the engine inoperative, the

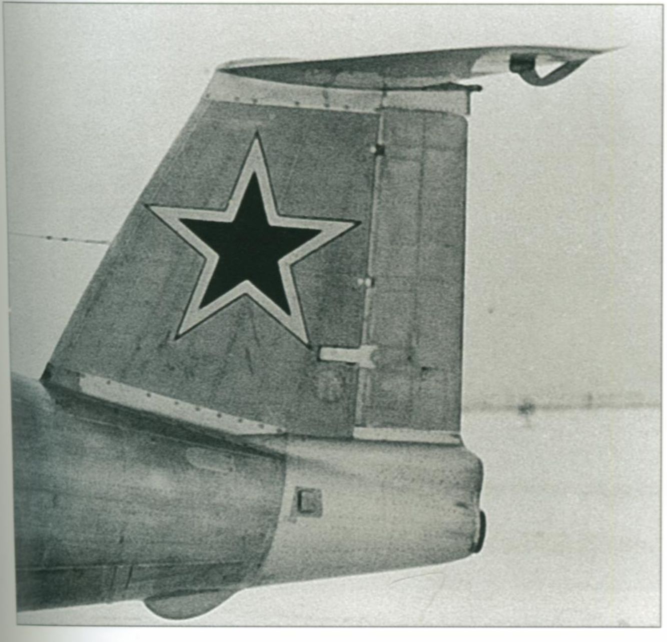


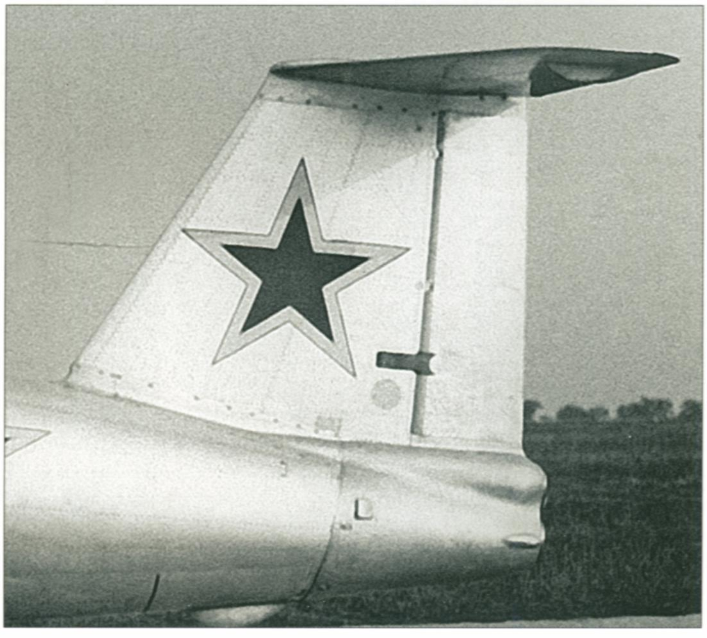


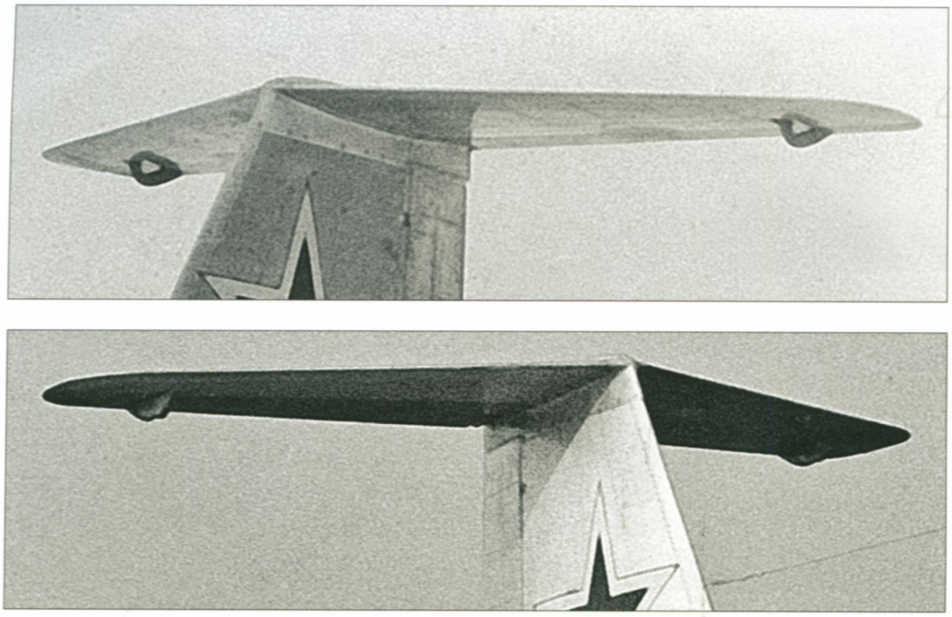












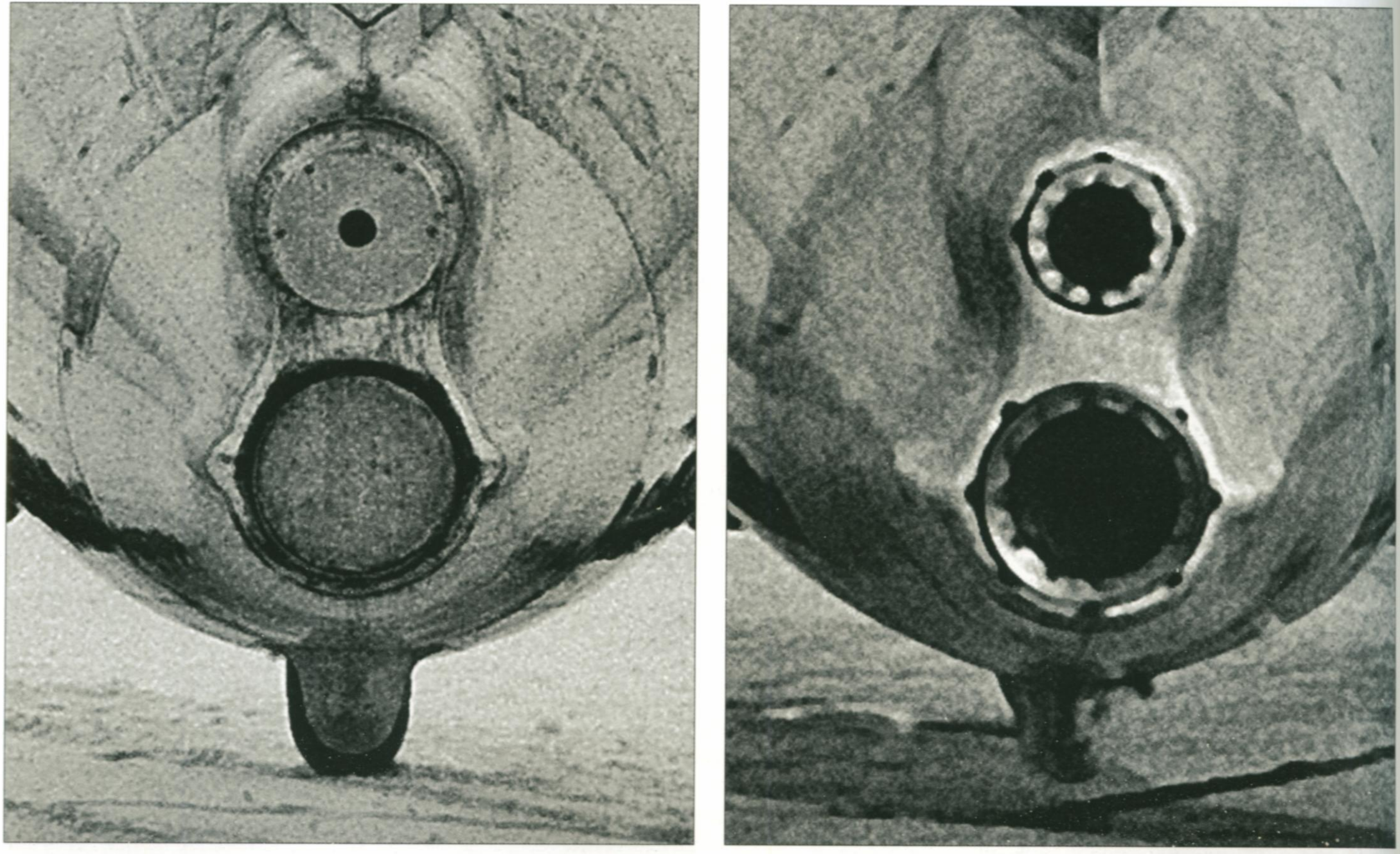
The horizontal tail of the first prototype (top) and the second prototype.

engine being shut down because of the short duration of its work;

- remnants of acid are eliminated by rinsing with water; this is unacceptable for winter operation of an aircraft with this engine;
- it is necessary to observe strictly the instructions for the use of nitric acid tanks, because the material of which the tanks are made is strongly affected by the acid vapours (a case was recorded when a nitric acid tank burst during a check-up test under pressure after two months' operation on the aircraft);
- according to instructions, after having been subjected to acid vapours in the course of two months the tank must be removed for a careful check-up; due to the large volume of the acid tank, its replacement on an aircraft of this design is very labour-intensive;
- the protective suits used by technicians during the servicing of the aircraft are bulky and inconvenient (the trousers and jacket are made of rubberised fabric), and are quickly worn out when attacked by the acid (the rubber boots and gloves).

Thus, the military were playing a game of wait-and-see. On the one hand, they did not want to have an interceptor of that kind introduced into service; on the other hand, they considered that MAP was obliged to develop the RD-2M3V engine to a high degree of reliability and safety, as well as to continue the experimental operation of a rocket-propelled aircraft for the purpose of accumulating experience of high-speed and high-altitude flights.

On 31st May 1948, after the machine had been reactivated, Air Force test pilot A. K. Pakhomov performed a 13-minute test flight which proceeded uneventfully. However, the people in the Ministry of Aircraft Industry were also unenthusiastic about working with hardware that had such a poor safety record. Therefore the I-270 interceptor was not flown again, and the question of failure to fulfil a Government task was simply hushed up with a mutual tacit consent of the MAP officials, the military and the designers of the aircraft. By that time it became obvious to everybody that liquid-fuel rocket motors were unsuitable for operation in service units of the Air Force and in the Air Defence fighter units. All the more so now that the first Soviet turbojets, offering far greater reliability of operation, were already entering production.



The rocket motor nozzles of the first prototype as originally completed (left) and the second prototype.

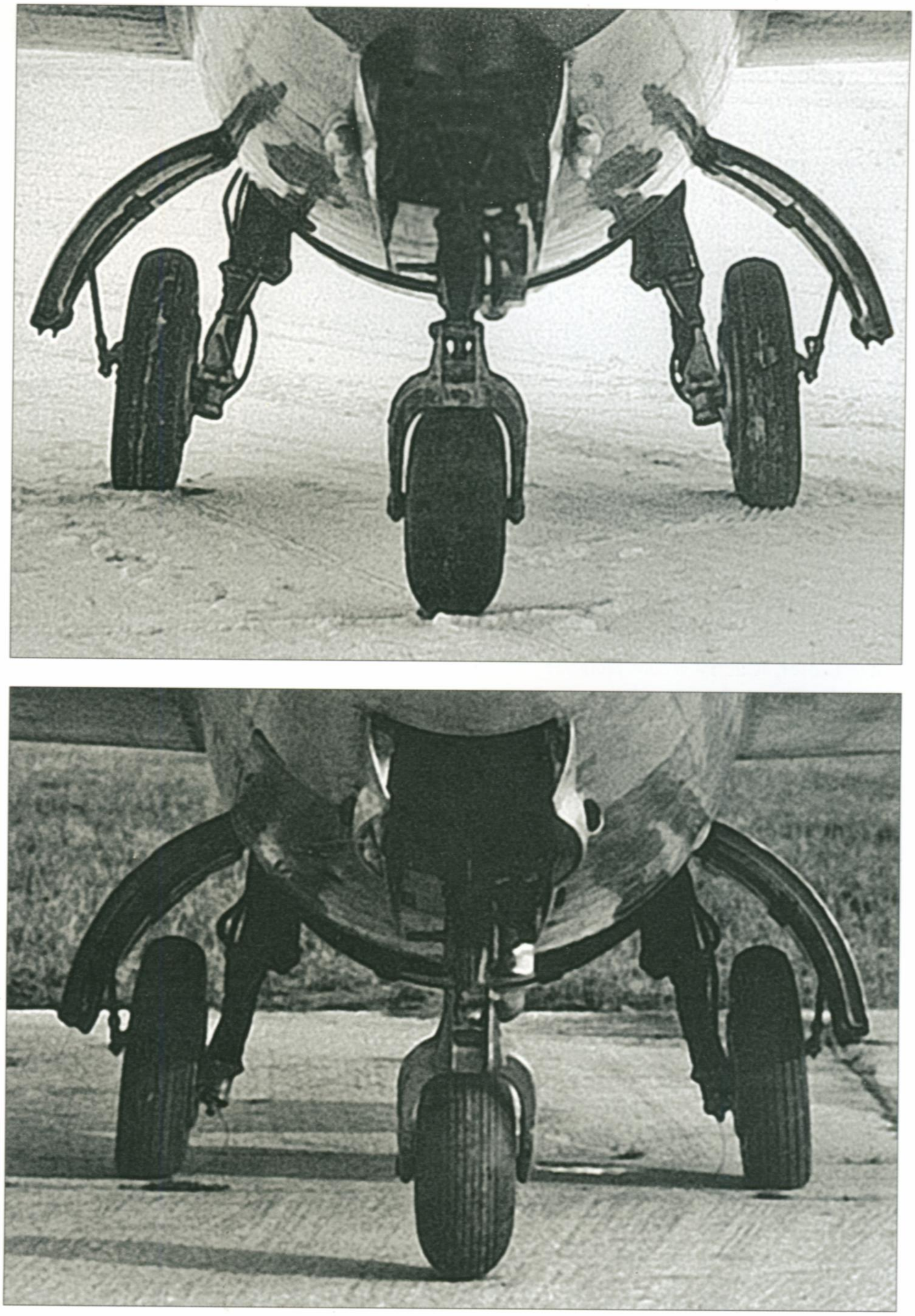
The I-270 ('Zh') Interceptor in Detail

The aircraft featured a normal aerodynamic layout with mid-set thin wings of trapezoidal planform and a T-tail.

Structurally, the I-270 ('Zh') was a cantilever mid-wing monoplane of all-metal construction. The structure was protected from the corrosive nitric acid vapours by using acid-resistant piping/fittings and an anti-acid protective coating. Depending on the degree of the acid's destructive influence on the airframe the fighter was conventionally divided into four zones: Zone 1 with the greatest degree of corrosiveness at normal temperatures; Zone 2, also with the highest degree of corrosiveness but at high temperatures (110-150°C/230-302°F); Zone 3 with a lower degree of corrosiveness, and Zone 4 comprising all the remaining elements of structure which were not subjected to the corrosive medium.

All electrochemically coated duralumin parts situated in zones subjected to corrosion were given several layers of a protective coating developed by the All-Union Institute of Aviation Materials (VIAM – *Vsesoyo***ozn***yy institoot aviatsi***on***nykh materi***ah***lov*). The number of layers varied, depending on the location of the part in question, and could be as many as nine. The protective coating was applied to the parts before they were mounted in the aircraft. After the assembly of the machine its whole structure additionally received a coat of paraffin/ceresin compound.

To monitor the condition of the structure, so-called 'witnesses' were installed in accessible places. They were formed by three plates (two of them made of duralumin and one made of steel) which had a different coating. One of the duralumin plates was covered with an anti-acid compound, the other was electrochemically coated and the steel plate had a coating of zinc.



The landing gear of the first prototype (top) and the second prototype.

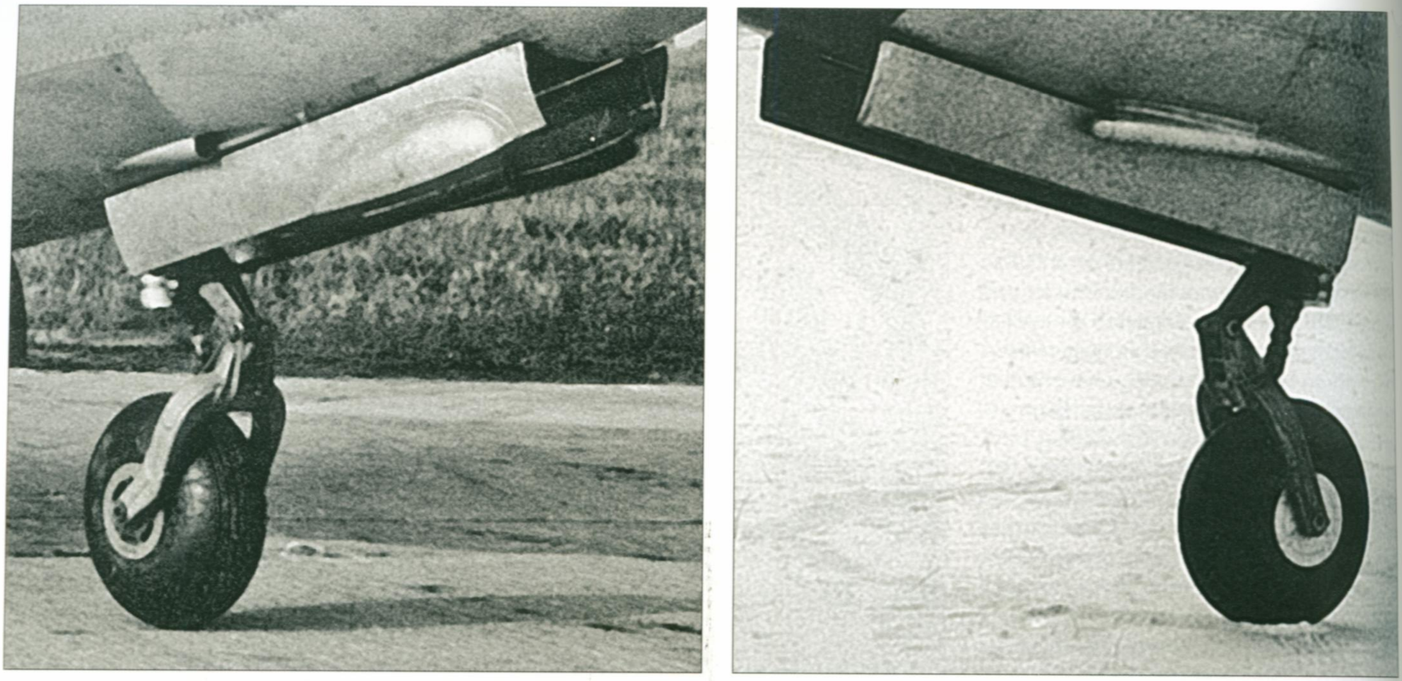
Fuselage: Circular-section, semi-monocoque structure with a break point at frame 10 to ease access to the units of the powerplant. The reinforced aft end frame carried the rocket motor (attached at four points) and the fin's rear spar. A cutout was featured in the centre fuselage for the installation of the wings.

The cockpit was located in the forward fuselage. The pilot was protected from enemy fire in the forward hemisphere by an armour plate 8 mm ($0^{21}/_{64}$ in) thick which formed part of the pressure cabin structure as its forward wall, and by a bulletproof windscreen 15 mm (0.59 in) thick in the cockpit windshield. The weight of the armour totalled 70 kg (154 lb). Pressurisation air was fed to the cockpit by a special Model 198A compressor.

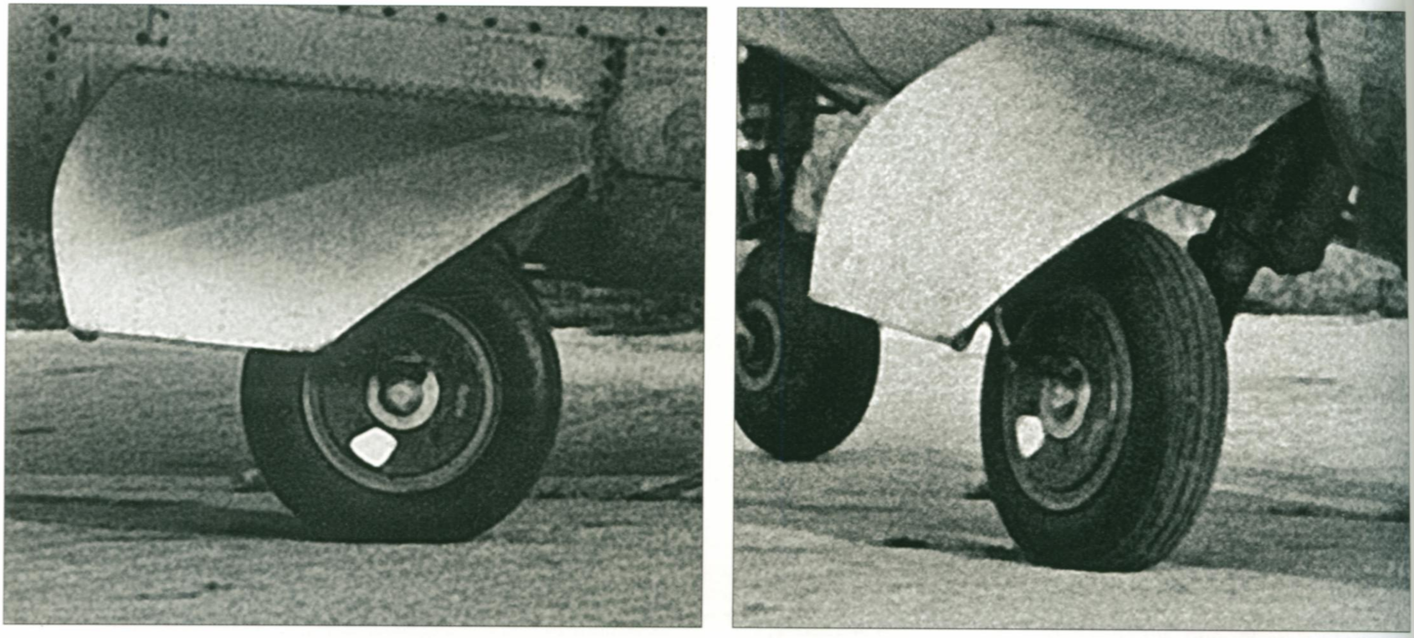
Wings: Cantilever mid-wing monoplane with thin wings of trapezoidal planform with an area of 12 m^2 (129 sq ft); leading-edge sweepback 12°, dihedral 2°, incidence +1°. The wings were a one-piece four-spar torsion box structure with thick metal skin panels. They were formed by TsAGI-12145 and TsAGI-1S1012 airfoils with a thickness/chord ratio of 12%. The wings were fitted with slotted flaps inboard and Frise ailerons outboard.

Tail unit: Cantilever T-tail of trapezoidal planform. The vertical tail with a one-piece rudder had 30° leading-edge sweep. The horizontal tail with one-piece elevators utilised a TsAGI-08045 airfoil with a thickness/chord ratio of 8%.

Landing gear: Pneumatically retractable tricycle type, with single wheel on each unit; all units retracted forward. The main units had 660 x 170 mm (27 x 6.7 in) brake-equipped wheels, the nose unit had a 480 x 210 mm (18.9 x 8.3 in) non-braking wheel. All units had oleo-pneumatic shock absorbers. The main gear units had a very narrow track – 1.6 m (5 ft 3 in) – and were stowed in the centre fuselage (a wheel well under the wing torsion box between frames 10 and 14). The nosewheel well was located beneath the cockpit and closed by twin doors. The mainwheel wells were closed by one-piece doors mechanically linked to the oleo struts.



The nose gear unit of the second prototype (left) and the first prototype. Note the cannon barrel fairings flanking the wheel well.



The port main gear unit.

Powerplant: The aircraft was powered by a Glooshko RD-2M3V twin-chamber liquid-fuel rocket motor delivering a maximum thrust of 1,450-1,490 kgp (3,200-3,285 lbst). The combustion chambers were located above one another in the aft fuselage. The engine ran on a mixture of 96% nitric acid and kerosene, and the turbopump assembly feeding the fuel and the oxidiser into the combustion chamber was powered by 80% hydrogen peroxide. The total amount of the propellants was 2,120 kg (4,675 lb).

All the pumps feeding the fuel into the rocket motor actuated the aircraft's electric system.

The fuel system comprised tanks of three types: four tanks for the acid, with a total capacity of 1,620 kg (3,570 lb), one kerosene tank holding 440 kg (880 lb) and seven tanks for hydrogen peroxide. The fuel and oxidiser tanks were housed in the fuselage near the aircraft's CG.

Control System: Conventional mechanical flight controls.

Electrics: The electric system comprised a 1.5-kilowatt GSK-1500 generator actuated by the turbopump assembly of the rocket motor, a GS-1000 generator located in the nose and actuated by a two-bladed vane (or ram-air turbine), and a 12A-10 storage battery.

Armament: Two 23-mm (.90 calibre) Nudel'man/Suranov NS-23 ('115P') cannons. The cannons and their ammunition boxes were located below the cockpit, the cannon barrels flanking the nosewheel well.

Avionics and Equipment: The aircraft's special equipment comprised a PKI-1 collimator gunsight, an RPKO-10 (or RPKO-10M) direction finder, an RSI-6 radio, an IFF system, a KP-14 oxygen unit, and an FSI-6M unit.

Chapter 6

The German Influence

German Experiments in the Soviet Union

'346' Experimental Aircraft

After the end of the war from which the Soviet Union emerged victorious and captured a sizeable amount of German military hardware and documentation, the Soviet authorities and experts were confronted with convincing evidence of the progress Germany had achieved in the field of military aviation. Examination of the captured materials could, to some extent, help to eliminate the lag in the field of aviation research and technologies; therefore the Soviet leaders gave this problem a most serious consideration.

In 1944 the German Research Institute for Gliding Flight (DFS – *Deutsches Forschungsinstitut für Segelflug*) prepared a project of the DFS 346 experimental aircraft, which was a follow-on to the DFS 228 subsonic high-altitude reconnaissance aircraft intended to be powered by the Walter HWK 109-509 liquid-fuel rocket motor – the same model as on the Me 163 interceptor. The DFS 228 was built in 1943 and was tested without the rocket motor, as a glider. Unlike this aircraft, the DFS 346 had swept-back wings and was expected to reach a maximum speed around 2,000 km/h (1,243 mph). To this end the aircraft was to be powered by a Walter twin-chamber liquid-fuel rocket motor. According to the project, the DFS 346 would be lifted to an altitude of some 10,000 m (32,800 ft) by a carrier aircraft (the Junkers Ju 388 bomber or the Heinkel He 219 Uhu night fighter were envisaged for this role) and then be released, continuing the flight on its own.

The construction of the experimental superfast aircraft began several months prior to the end of the war and was halted during the closing stage of the war when the hostilities moved to German territory.

It is well known that during the post-war period the Soviet authorities set up several research and development organisations for the purpose of making use of the German scientific and technical potential. Several design bureaux were set up in the field of aviation; they were located in Dessau, Berlin, Halle and in other places. One of them, the so-called OKB-3 in Halle, was organised in late 1945 on the basis of the Siebel Flugzeugwerke KG aircraft production company. It was engaged in the design of not only aircraft but of aircraft engines as well. Since the Siebel company was a relatively small enterprise, OKB-3 had a much smaller design staff as compared to OKB-1 in Dessau (the former Junkers company) and OKB-2 in Stasfurt. In December 1945 the staff of OKB-3 comprised only 41 persons, including 12 designers, four engineers for calculation tasks and two aerodynamicists. Soon, however, attracted by the food rations offered by the Soviet authorities (no small benefit in the war-ravaged Germany), more former Siebel employees joined OKB-3 which also recruited some specialists from the Heinkel and BMW companies. Thanks to all this, the strength of the OKB's personnel grew considerably and in March 1946 as many as 742 persons worked there. General management of the design bureau was effected by Vlasov, a representative of the Soviet Ministry of Aircraft Industry, and by Doctor Seitz, one of the former directors of the Siebel company. Hans Rössing, a German engineer, was appointed Chief Designer of OKB-3.

In terms of internal structure, OKB-3 was divided into two sections dealing respectively with aircraft and aero engines. It was this body that was tasked with resuming the work on the projected DFS 346 experimental aircraft. On 17th April 1946 the Soviet Council of Ministers issued directive No.874-366ss which tasked the design bureau led by H. Rössing with developing the Siebel Si 346 experimental supersonic aircraft capable of attaining a speed of 2,500 km/h (1,554 mph) at an altitude of 20,000 m (65,600 ft).

In early 1946 OKB-3 started manufacturing a full-scale mock-up, producing the jigs and tooling and preparing detail drawings of the aircraft. N. A. Heifitz was appointed project engineer for the Si 346 from the Soviet side; on the German side the work on the aircraft was directed by Chief Designer H. Rössing, engineer Heinsohn (who was chief of the aircraft section's design team) and others. Substantiating the expediency of work on the aircraft, Heifitz wrote:

'The Siebel-346 aircraft is a flying laboratory intended for studying the problems related to flight at supersonic speeds. (Note: The Russian term *le**ta**yuschchaya labora**tor**iya* – lit. 'flying laboratory' – means 'flying testbed' or 'research/survey aircraft' – *Auth.*)

Penetration into the field of high speeds and exploration of the conditions of these flight modes has long been a matter of interest for science. In this case not only the methods of studying the problems associated with these flights are new; so is the flight itself: an aircraft's behaviour in supersonic flight modes, flight dynamics, stability, controllability, the variation of the drag curve and so on.

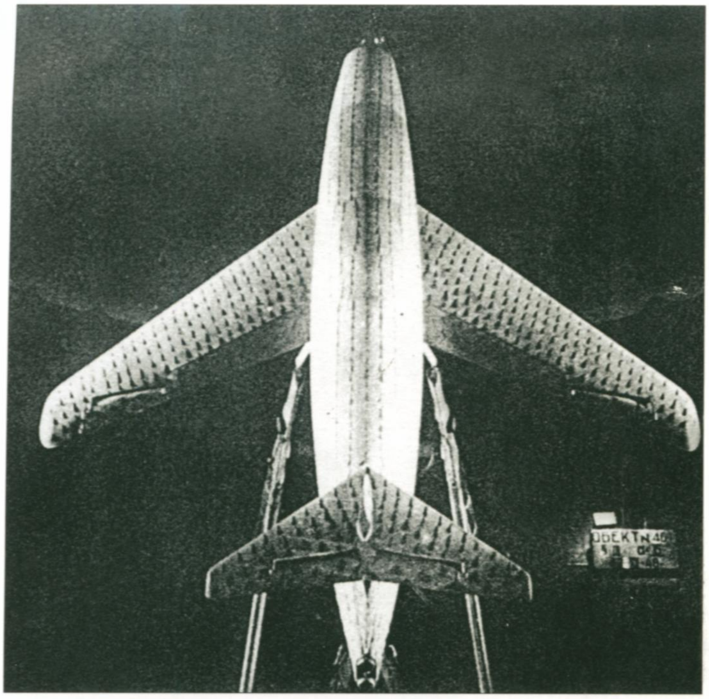
Hans Rössing, Chief Designer of OKB-3, supervised the further development of the German DFS 346 aircraft in the USSR.

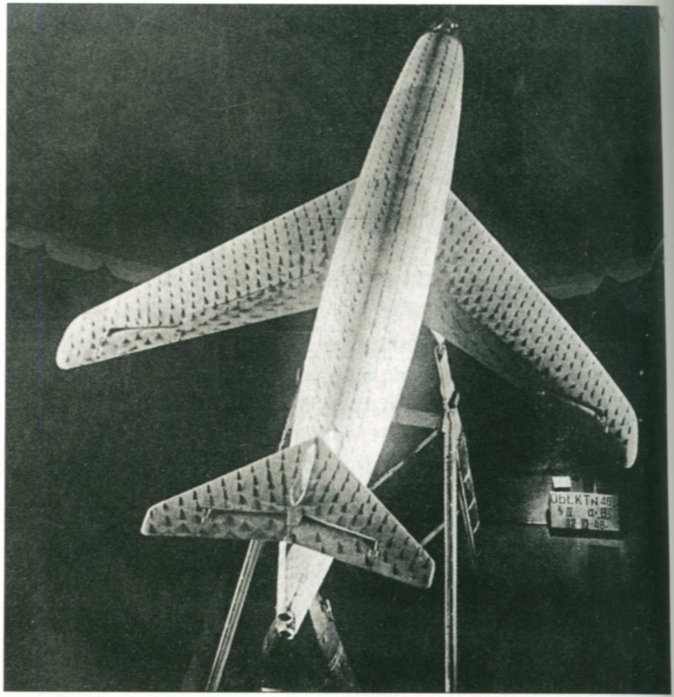
Studies conducted on models in supersonic wind tunnels do not give reliable results at present. Wind tunnels having a huge power consumption and dealing with small models do not produce reliable results because of difficulties in assessing the scale effect.

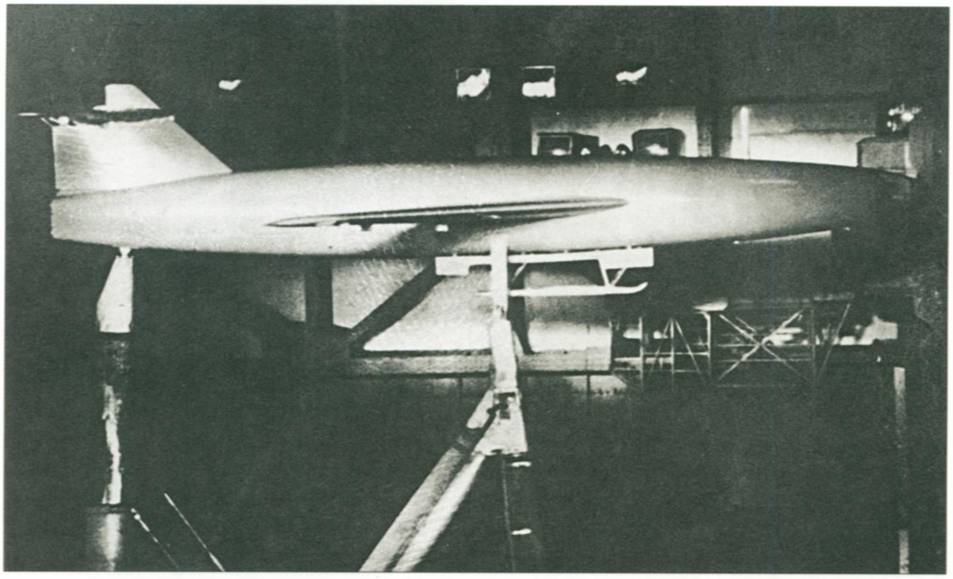
Testing and exploration of these phenomena in flight has always been one of the most enticing and at the same time the most difficult of tasks. The Siebel-346 aircraft is intended to fulfil this task'.

Here is one more quotation from a report prepared by MAP specialists on aviation research conducted in Germany in 1945-46:

'Despite insufficient argumentation to support the project, the aircraft is of great interest as an attempt to undertake the quickest intrusion at random into the field of supersonic speeds, all the more so since factory test pilot Motsch has expressed his wish to conduct tests of this purely experimental aircraft.'





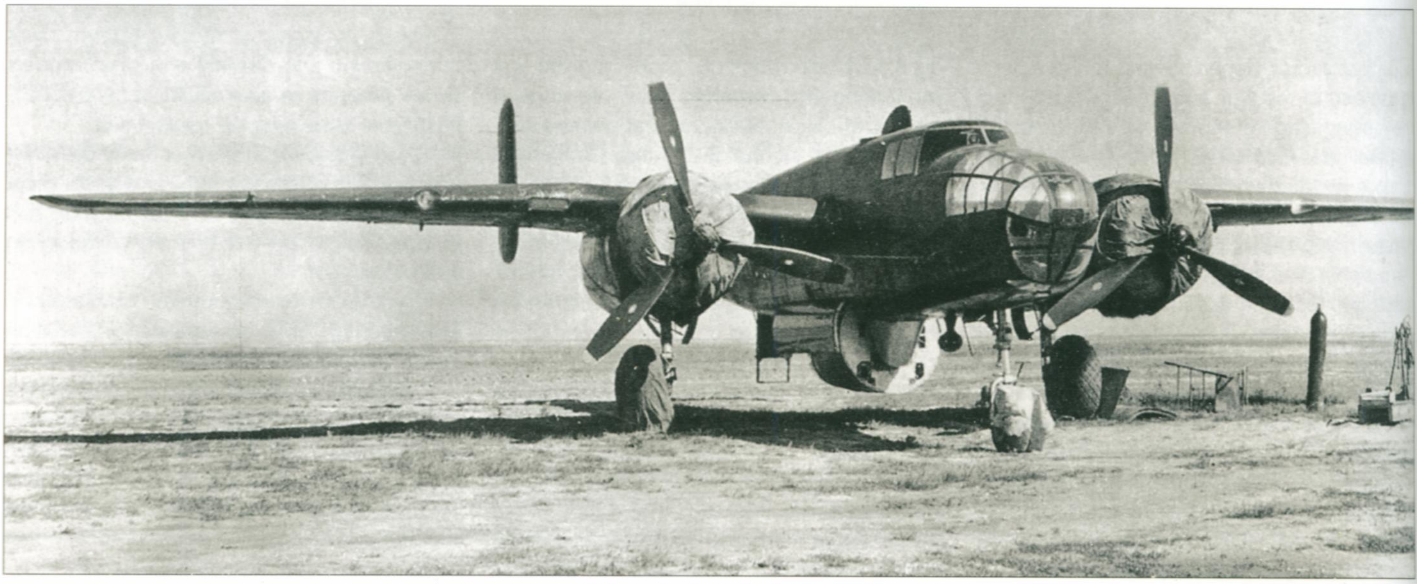


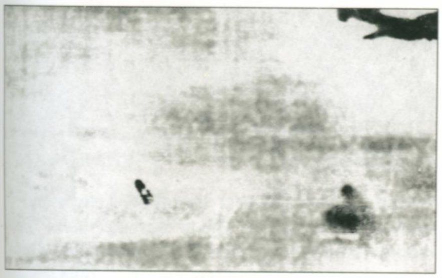
Above and above left: The first prototype of the DFS 346 in TsAGI's T-101 wind tunnel on 12th November 1948; the aircraft has been designated 'object 46' for the occasion. The upper surfaces of the wings, fuselage and horizontal tail are covered in wool tufts for airflow visualisation.

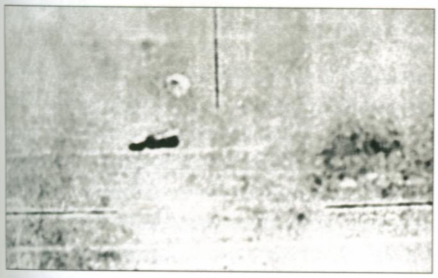
Left: Another view of the DFS 346 V1 in the wind tunnel, showing the control surface above the stabilisers (the so-called *Paddel*) and the landing skid with its bay doors.

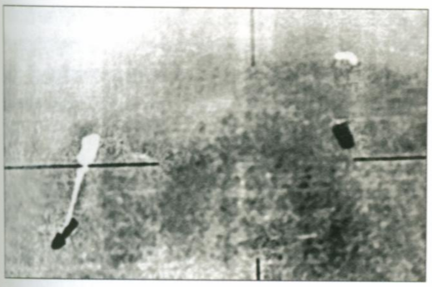
Below: This North American B-25J Mitchell operated by LII was used to test the DFS 346's rescue system featuring a jettisonable cockpit. Here the complete cockpit is suspended under the bomber's fuselage, ready for paradropping.

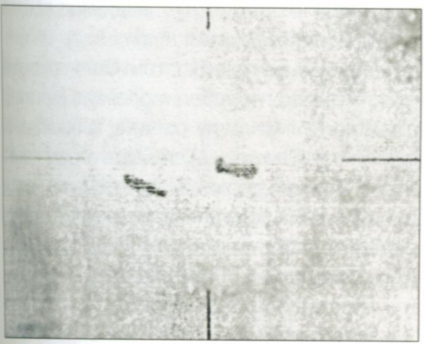
Right: This sequence of stills from a cine film shows the DFS 346 cockpit falling away from the B-25; next, the stabilising parachute opens and the pilot's berth separates, allowing him to use his parachute. The bottom picture shows the cockpit section lying where it has fallen.

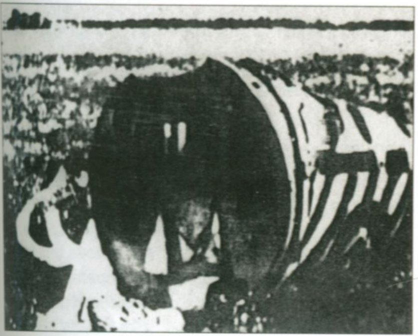


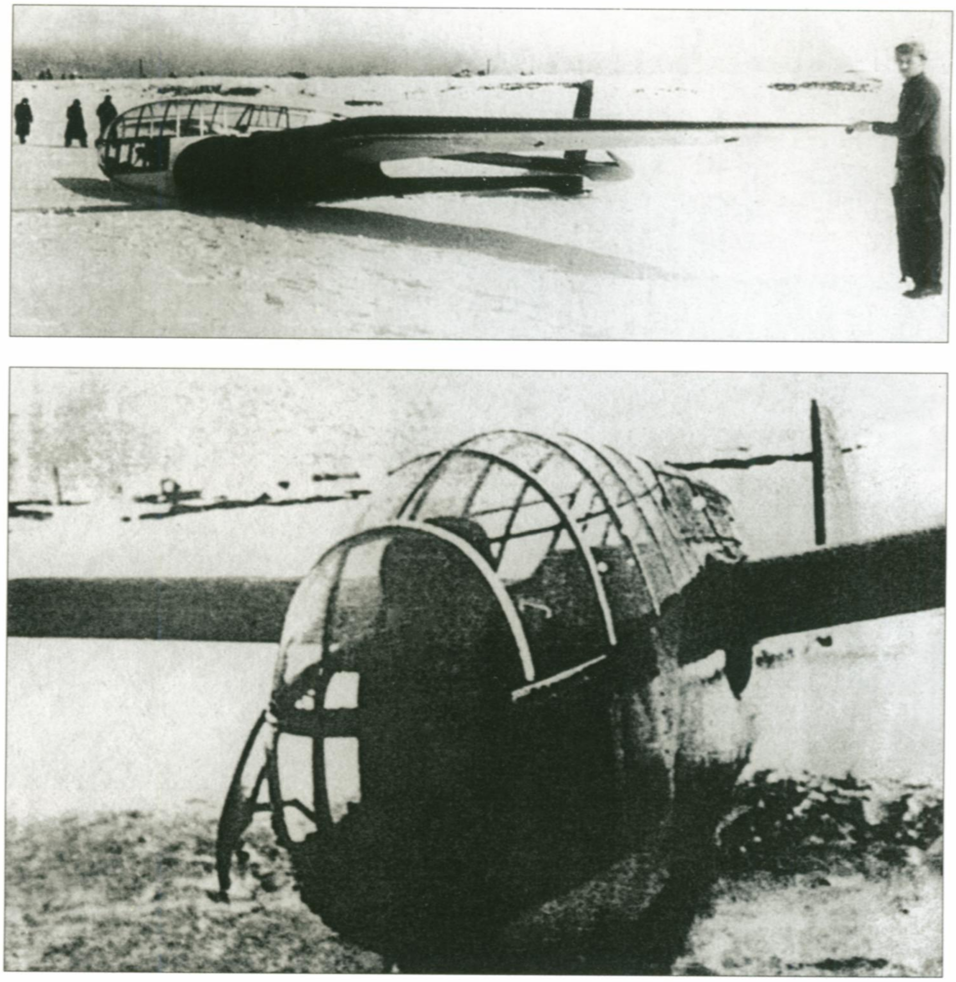












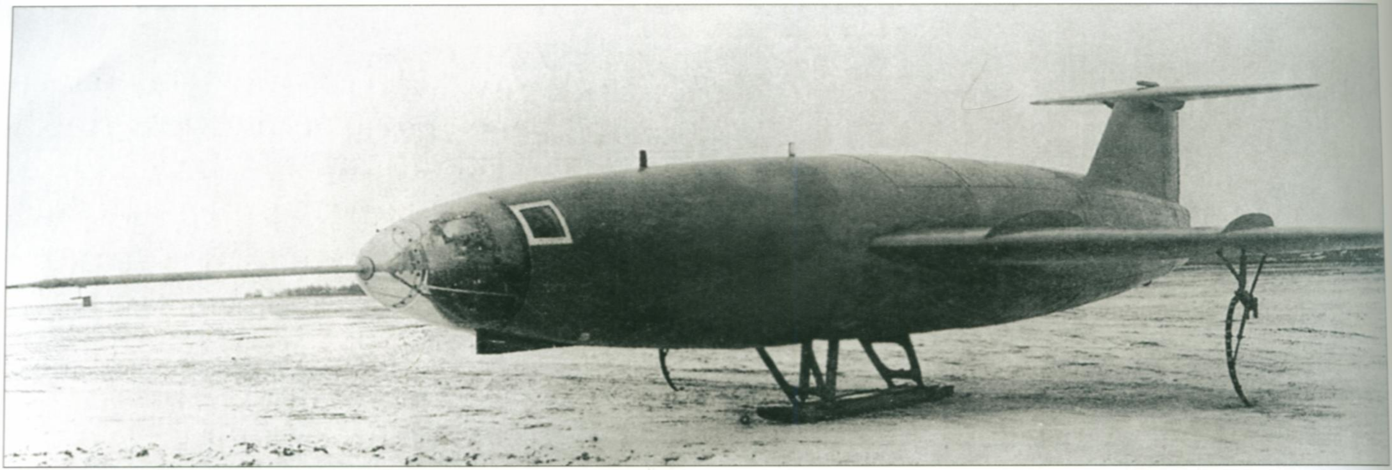
Top and above: Before flight tests of the '346' could begin, a German-built Kranich sailplane – also designed by DFS – was modified to verify the possibility of controlling an aircraft while lying prone.

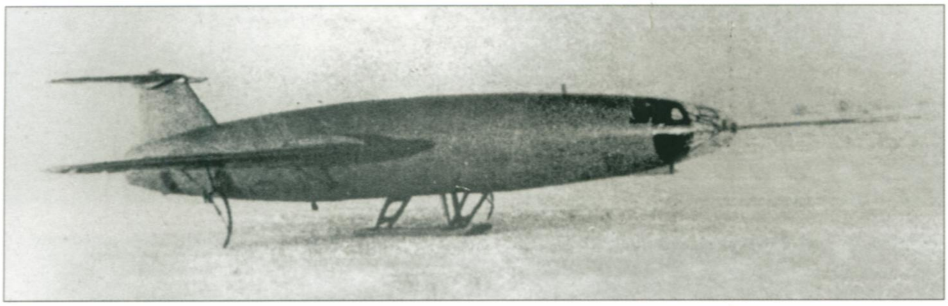
In late July 1946 a discussion of the project of the Siebel-346 aircraft was held at OKB-3; it took place in the presence of Deputy Minister of Aircraft Industry M. M. Lukin who had arrived from the USSR. In accordance with the decisions taken at the meeting, some changes were introduced into the aircraft's design; among other things, pressurisation of the fuselage was improved and landing skids were added at the wingtips to protect them during landing.

On 29th September 1946 the recently completed first prototype of the aircraft was rolled out at the aircraft factory in Halle. The second flying prototype was only 40% complete by then, but the static test example was fully completed. At the beginning of October the preliminary ground testing of the first flyable example, designated DFS 346 V1 in keeping with German practice (V = *Versuchsmuster* – development article, or prototype), was begun.

Here mention must be made of the problems associated with the German liquid-fuel rocket motors. The engine section of OKB-3 was expected to deal with the manufacture of the Walter 109-509 rocket motor for the DFS 346 aircraft and to engage in the study of alternative types of liquid-fuel rocket motors. It was headed by the Soviet engineer Berglezov; German collaborators included K. Schell from BMW, W. Küntzell from the Walter company and G. Reck from the German Aviation Experimental Establishment (DVL – *Deutsche Versuchsanstalt für Luftfahrt*). Yet, there was some shortage of highly qualified specialists

Wolfgang Ziese, the 346's project test pilot.





Left and above: The first prototype in engineless form known as '346P'. The aircraft has been modified: the *Paddel* is gone, and boundary layer fences have been added to the wings. Note the small outrigger skids under the wings and the absence of the main skid bay doors.

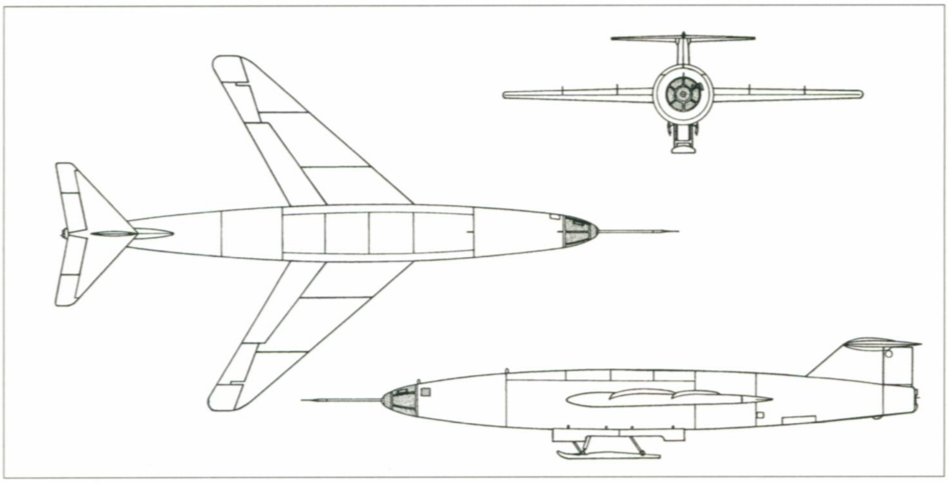
on liquid-fuel rocket motors. Chief of OKB-3 Vlasov wrote in his report in May 1946:

'There are no designers, technologists and engineers qualified in engine design and construction. Lists and addresses of the required specialists are available and have been submitted by us to the appropriate organisations […] Up to now the specialists have been collected by the officers of the Special Technical Bureau, but, since a number of specialists live in the occupation zones of our Allies, we need immediate assistance from appropriate organisations

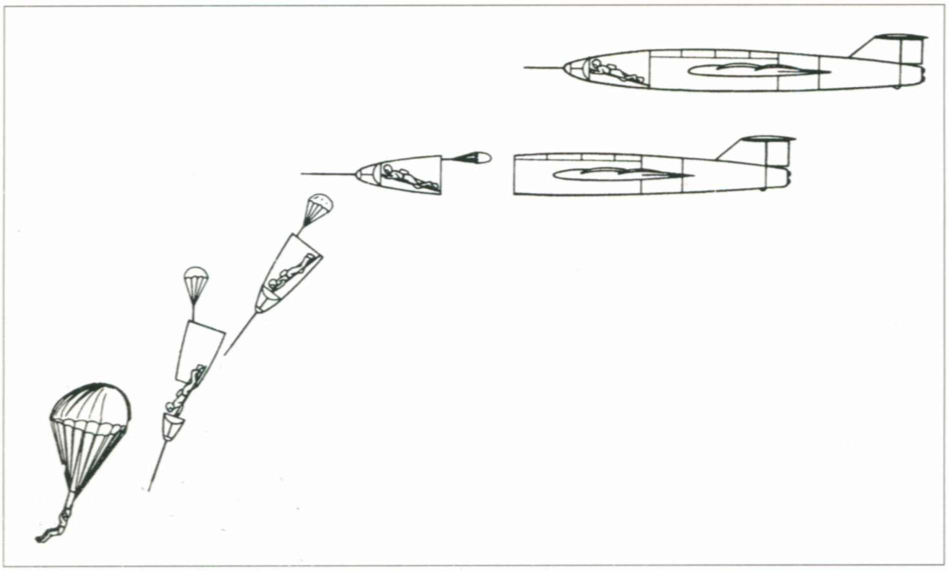
During the recent time many valuable specialists on liquid-fuel rocket motors have been taken over by the Allies. […] In the present situation the Special Technical Bureau is forced to use specialists from other fields of technology and to instruct them in modalities of work on the liquid-fuel rocket motors.'

It should be noted that the German rocket motor was a production model and it proved possible to find many parts for it at different facilities in Germany. The same report noted that it was possible to assemble up to 14 rocket motors from the available stockpile of parts (provided that these parts underwent major overhaul and some missing parts were manufactured anew).

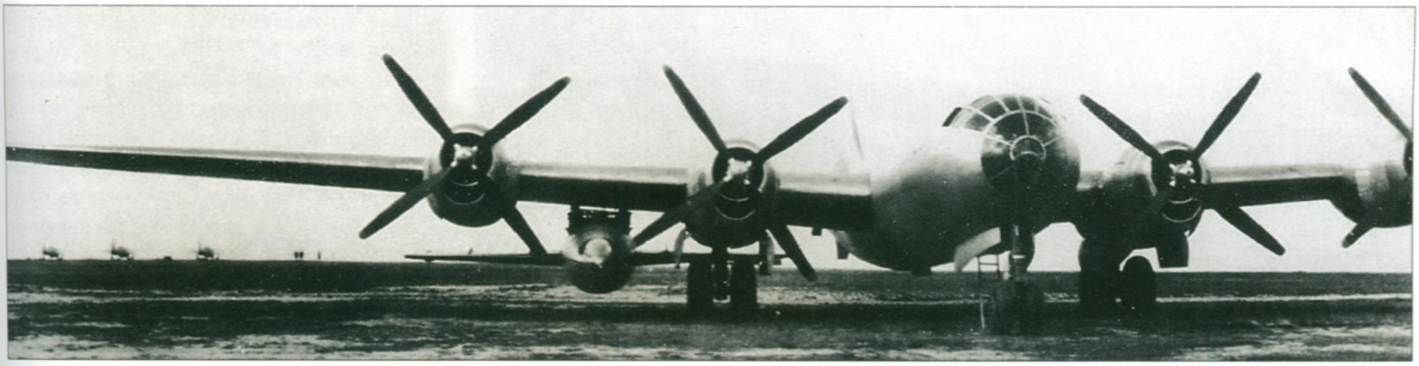
By the autumn of 1946 the engineers of OKB-3 had completed the assembly of seven engines with a thrust rating of more than 1,700 kgp (3,750 lbst) and of two modified models (Walter 109-510) yielding a thrust of up to 2,000 kgp (4,410 lbst). In addition, benches were manufactured for testing these



Above left: The '346-1' in the configuration depicted above but with the main skid bay doors in place.

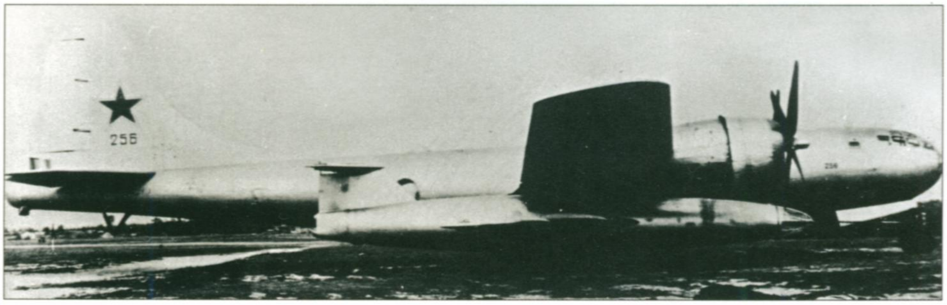


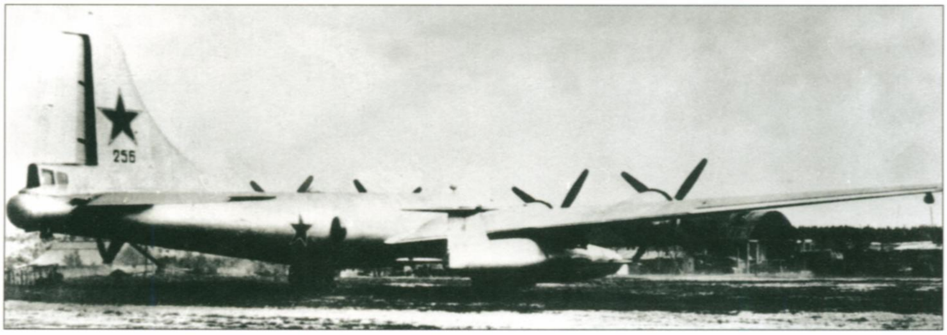
Left: This sequence illustrates the operation of the rescue system as the cockpit is jettisoned, the pilot separates from it and opens his parachute.

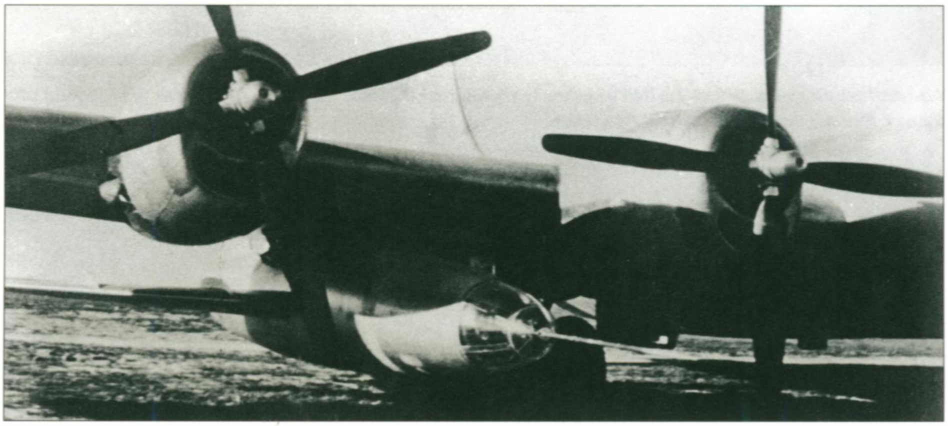


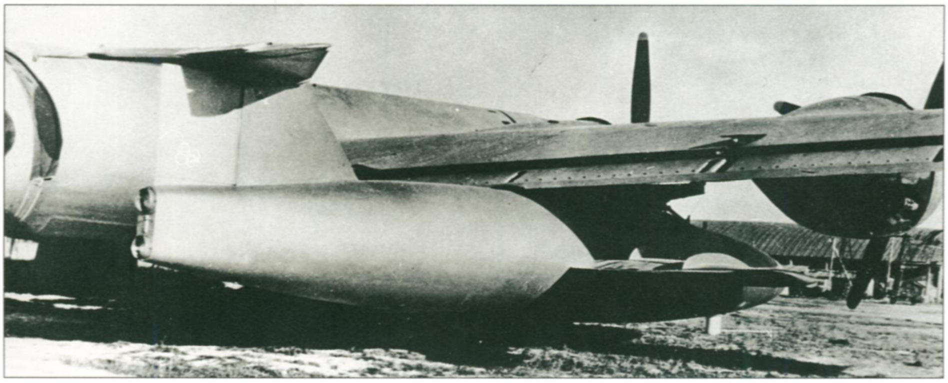
engines. However, the testing of the liquid-fuel rocket motors never started due to the unavailability of the proper fuel. A thorough search of the Soviet occupation zone turned up some 55 tonnes (121,250 lb) of fuel components for the liquid-fuel rocket motors developed by the Walter and BMW companies, but their chemical composition made them unsuitable for use. This was the main reason making it impossible to start the testing of the DFS 346 V1.

In October 1946 the staff of OKB-3, together with the other collectives of interned German specialists, was relocated to the Soviet Union for further work. All the captured hardware, including the DFS 346 V1 experimental aircraft, was dismantled and also sent to the USSR for examination, wind tunnel tests and flight testing. By 7th November all aviation specialists that had come from Germany had been distributed and assigned to various MAP enterprises. Specialists in aircraft construction were grouped at the experimental plant No.1 (formerly a plant producing hydroplanes) situated in the settlement of Podberez'ye, some 100 km (62 miles) north of Moscow, while the turbojet engine specialists were sent to the experimental plant No.2 situated in the Volga region, not far from Kuibyshev (at present Samara). Two new design bureaux were organised at plant No.1 – OKB-1 under Chief Designer Brunolf Baade and OKB-2 led by Chief Designer Hans Rössing. It was the latter design team that was tasked with continuing the work on the DFS 346 aircraft. Interestingly, the post of Rössing's deputy was occupied by Aleksandr Ya. Bereznyak, the chief designer of the BI – the first Soviet rocket-propelled interceptor, who had a lot of experience in developing such aircraft.



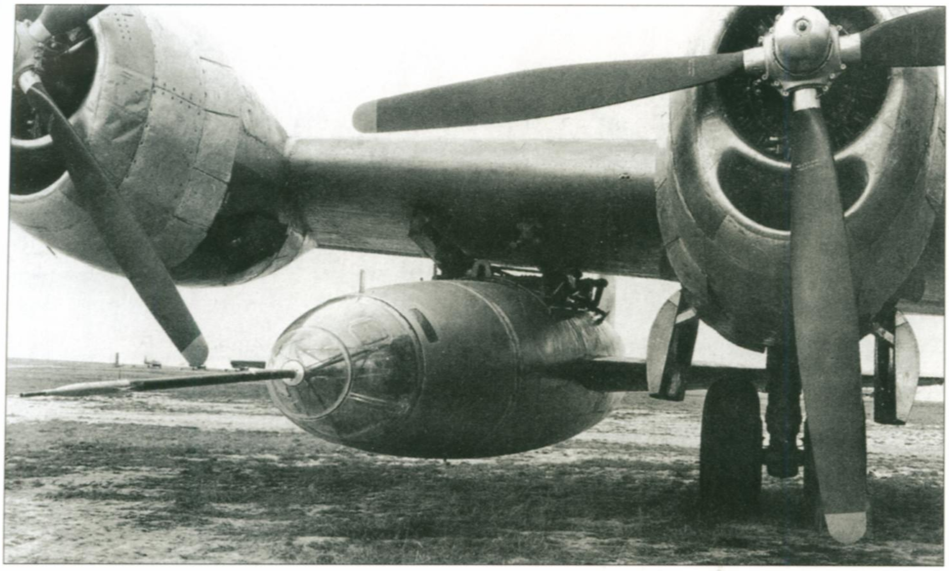




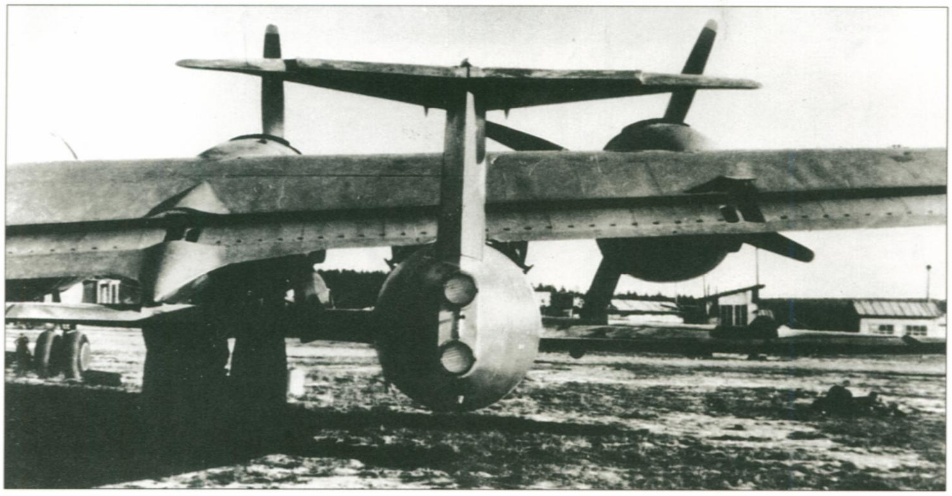


Top of page, upper centre and centre: Boeing B-29-5-BW '256 Black' (ex-42-6256) was used as the carrier aircraft during Stage 1 of the 346's initial gliding trials. Here, the 'mother ship' with the '346-1' attached is seen at Tyoplyy Stan airfield near Moscow.

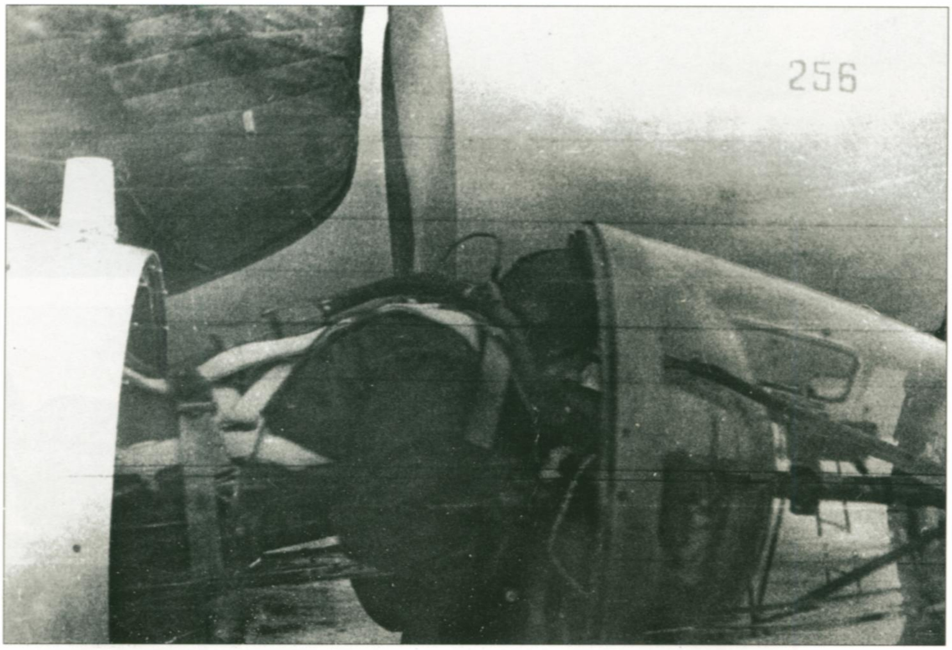
Right and above right: Close-ups of the '346-1' suspended on a rack between the B-29's Nos 3 and 4 engines. Note the cutout in the flaps preventing them from striking the fuselage of the '346'.



Above: This view gives details of the special rack on which the '346-1' was carried under the starboard wing of B-29 '256 Black'.



Above: This rear view shows the 346's vertically paired rocket motor nozzles. The nozzles are blanked off, since a dummy motor was fitted at this stage.



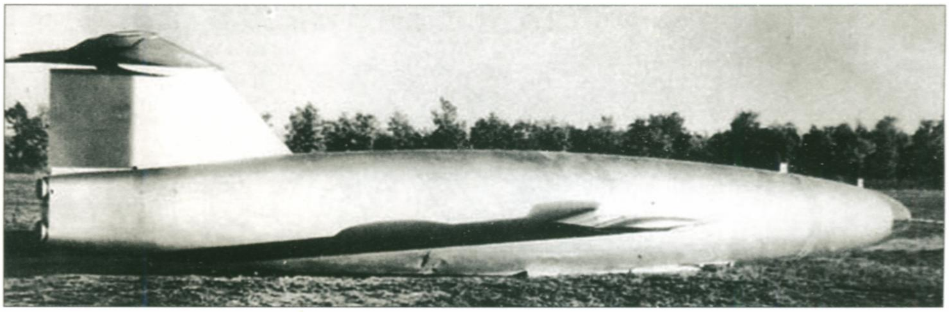
Entering the '346' was a tricky procedure. Here, Wolfgang Ziese lies strapped to his berth before the latter is slid aft together with the Perspex nosecone, which is then secured and the cockpit pressurised.

The Soviet staff of OKB-2 and of the production facility consisted of former employees of plant No.458 and young specialists who had just graduated from institutes and were assigned their jobs as per normal Soviet practice; therefore the end of 1946 and the beginning of 1947 were largely a preparatory period. The work on furnishing the necessary equipment to plant No.1 continued until the end of 1947. In addition to the existing production facilities, the plant was provided with a mechanical laboratory, a static test laboratory and a chemical laboratory; a wind tunnel affording speeds up to Mach 1 was built on the premises, as were test benches for liquid-fuel rocket motors.

In the USSR the German DFS 346 experimental aircraft was referred to simply as the '346'; in addition, in OKB-2 it was unofficially dubbed 'Victoria'. The work on it lasted quite some time, the designers delayed the final choice of the layout; the progress of the work was also affected by the interned German specialists' generally poor living conditions.

In the meantime, the DFS 346 V1 delivered from Germany was sent to TsAGI for aerodynamic research. The experiments were conducted in the big T-101 wind tunnel which allowed full-size aircraft to be tested. The tests showed that, owing to the wing sweepback, severe stalling took place at the wingtips when the wings were at high angles of attack; the stall quickly spread over the entire wing surface, causing loss of stability. This was not unexpected, since airfoils of the same type were used along the entire span, which is undesirable for swept wings. To eliminate this deficiency, it was recommended that four wing fences (two on each wing panel) be installed on the upper wing surface. After the wind tunnel tests the aircraft was also subjected to a structural strength check. Later a model of the '346' was tested in the T-106 – the USSR's first supersonic wind tunnel. Due to the loss of control authority at transonic speeds the maximum admissible Mach number in flight was limited to 0.8. To minimise drag the cockpit of the DFS 346 was designed so that the pilot was to fly the aircraft in a prone position; therefore preliminary experiments were conducted by LII to study the peculiarities of piloting an aircraft so configured. The German DFS Kranich (Crane, the bird) sailplane was used for this purpose, with its cockpit refitted for a prone pilot. The sailplane had high-aspect-ratio gull wings. It was towed to an altitude of 5,000 m (16,400 ft) by a Pe-2 dive bomber and then released to perform free flight. In 1948 this sailplane was flown by German pilot-engineer Wolfgang Ziese who had a 20-year record of flying experience. He had graduated from a flying school attached to the Hannover Aviation Institute. Large-scale research was also conducted

Above: Test pilot P. I. Kaz'min, who flew the 346 after Ziese's landing mishap.

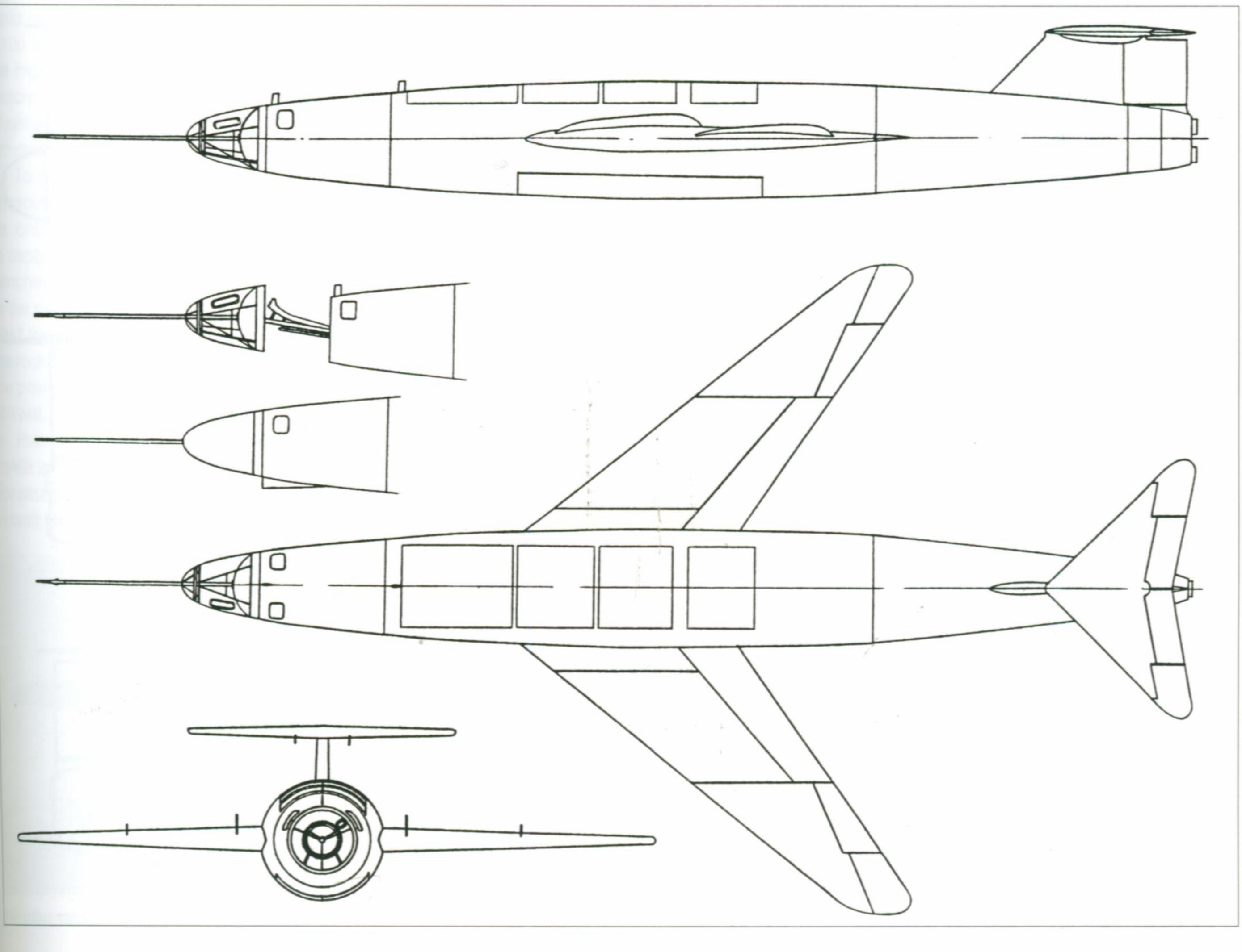


Above right: The first prototype lies on its belly after coming to grief on 30th September 1949.

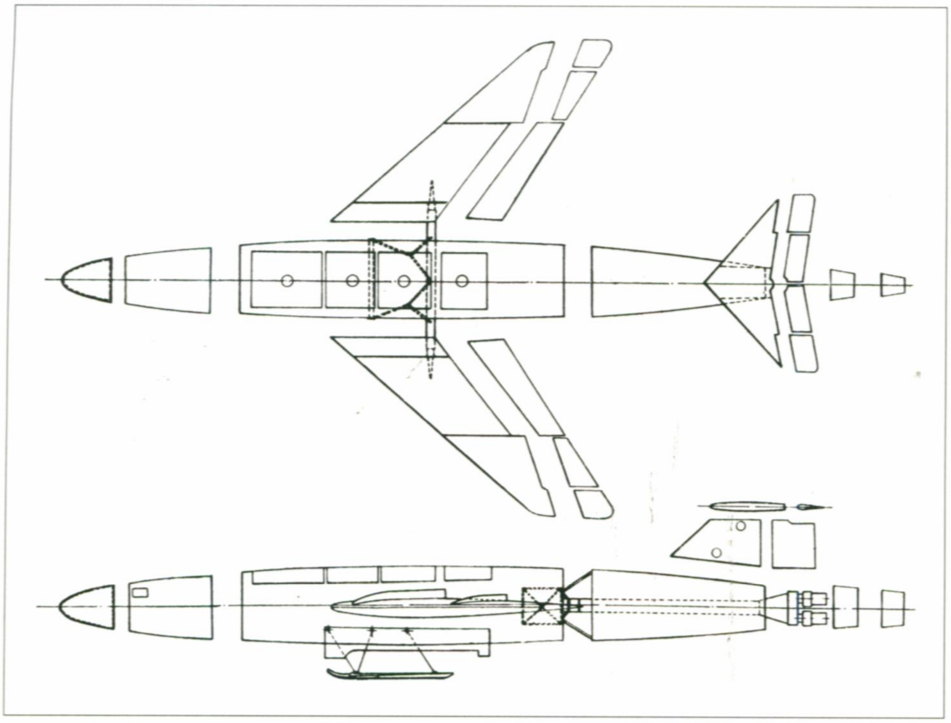
with regard to the take-off and landing device – the metal skid.

Test pilot Mark L. Gallai, who had flown this machine, later recalled that the prone position of the pilot proved to be very inconvenient for piloting, as might be expected. Nevertheless, it was decided not to return to the conventional position of the pilot; the idea of fitting the '346' aircraft with a protruding cockpit canopy was dropped because this would have necessitated an almost complete revision of its general layout which, in turn, would have entailed an inevitable increase of drag. LII specialists also conducted the testing of the detachable cockpit and the ejection device. For this purpose the cockpit of the '346' aircraft was suspended under the fuselage of a North American B-25J Mitchell bomber and was dropped in flight. The tests passed successfully.

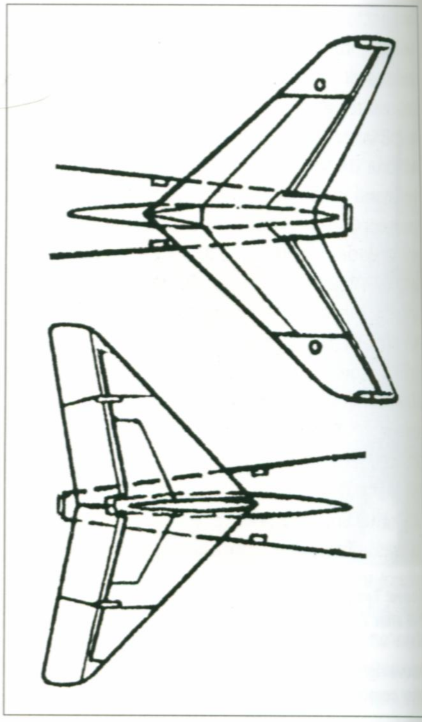
In its final configuration the aircraft was a mid-wing monoplane of metal construction (with the exception of the cockpit which had a wooden framework) with wings swept back 45°. As already noted, the pilot lay prone in the fuselage. In addition to reducing the fuselage cross-section and hence drag, this arrangement enabled the pilot to sustain greater G loads than in the traditional seated position. The transparent nosecone with Perspex glazing slid forward to give the pilot access to the cockpit. The latter had provisions for a conventional seat (to be used for testing the airframe) and a berth for the prone



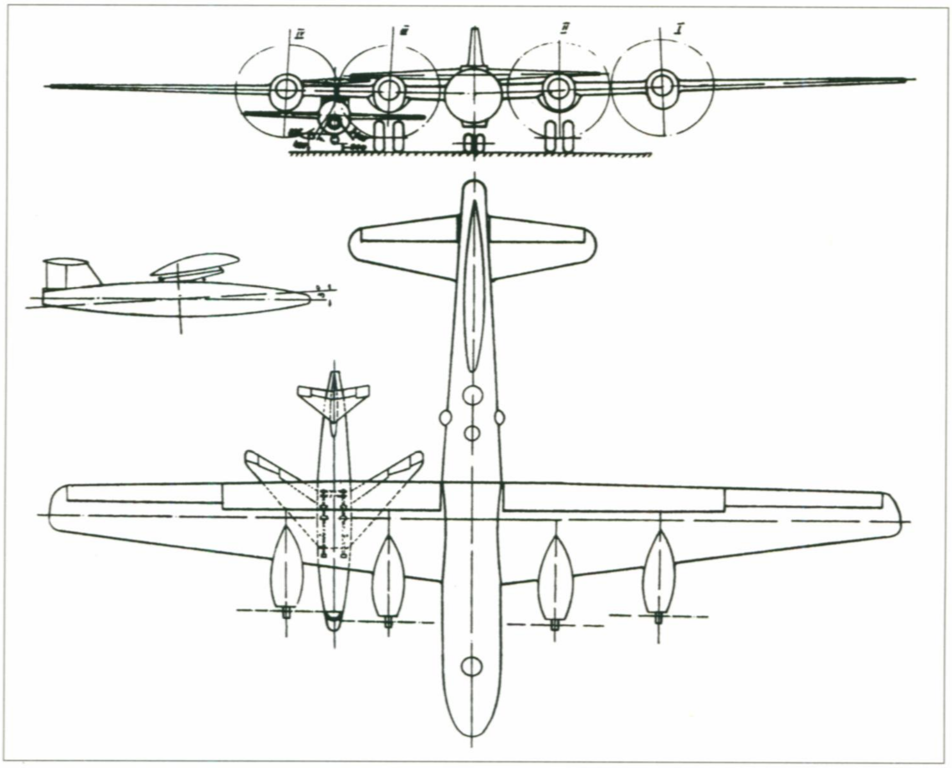
Below: A three-view of the '346-1' as it was flown; note the reverse-tapered ailerons. The scrap views show the canopy in the open position and the forward fuselage of the '346P'.



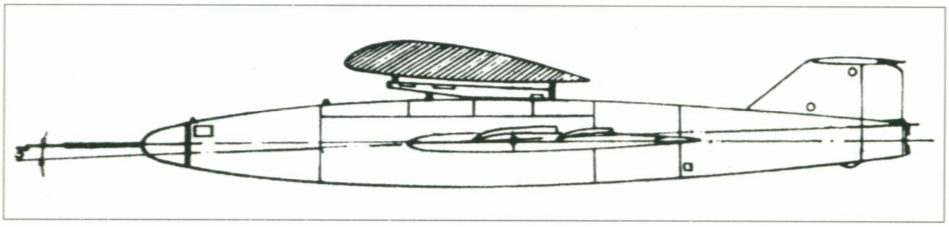
An exploded view of the '346-1'.

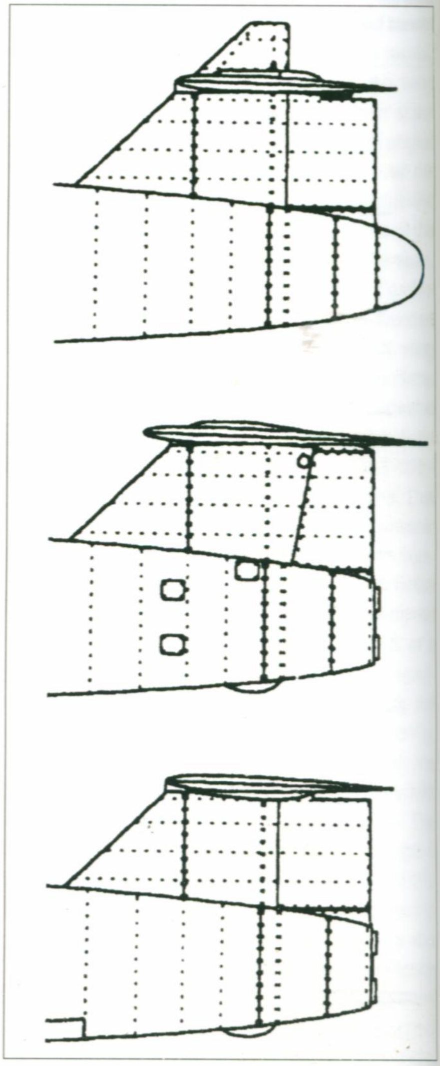


The horizontal tail of the DFS 346 V3 (or '346-3', top) and the '346-1'.

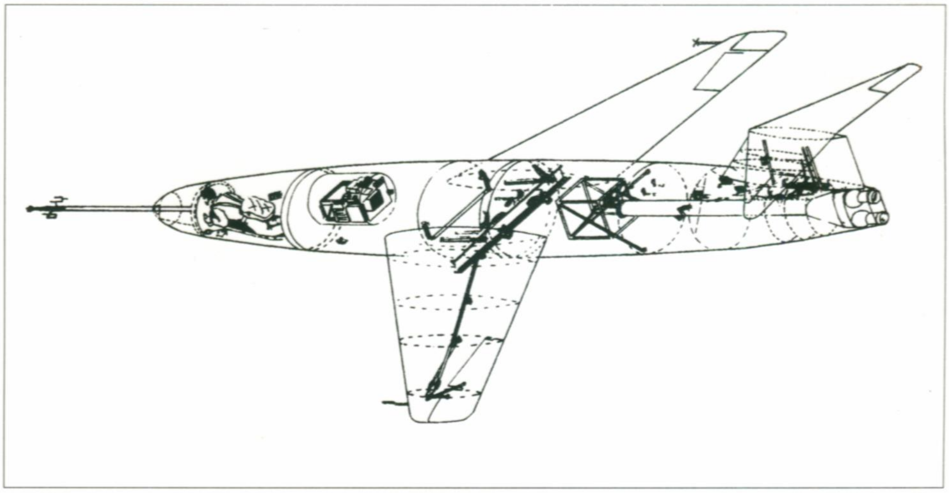


The drawings above and below show how the '346-1' was attached to the carrier aircraft in a 5° nose-down attitude.

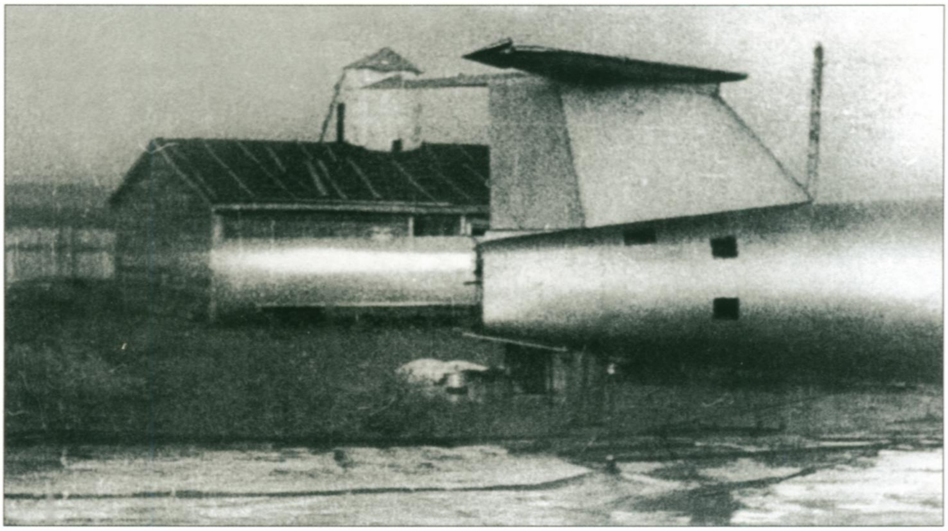




Right, top to bottom: The tail unit of the DFS 346 V1 as tested in the wind tunnel, the '346-3' and the '346-1'.



Above: A cutaway drawing showing the DFS 346's detachable cockpit with its parachute system, the location of the rocket motor and control system components.



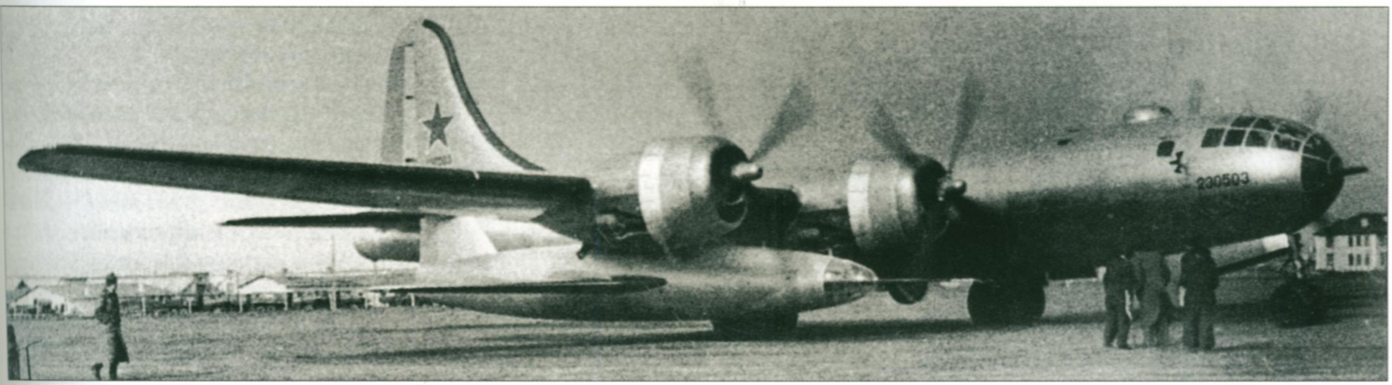
Above: Test-firing the upper chamber of the 346 V3's rocket motor in 1950. Note the revised tail unit with increased stabiliser sweep and a tapered rudder.

pilot. The aircraft was provided with an unconventional rescue system for the pilot. The pressurised cabin (which had been tested in a thermal vacuum chamber at LII and modified upon testing) was attached to the fuselage by explosive bolts and could be jettisoned in an emergency. Attached to the rear wall of the cabin was a parachute which was intended to stabilise its descent after separation. At an altitude of 3,000 m a system ejecting the pilot was actuated automatically, the canopy separated and the pilot together with his berth was ejected from the cabin, whereupon his parachute deployed at an altitude of 1,500 m (4,920 ft). The rescue system ensured that the pilot would 'abandon ship' even if he had lost consciousness. In this situation the separation of the pressurised cockpit was effected automatically – the electric fuse of the explosive bolts was brought into action. The landing gear consisted of a skid retracting into the fuselage. The absence of a normal wheeled undercarriage was due to the fact that the '346' was to be taken aloft by a carrier aircraft (a 'mother ship'). The powerplant consisted of a Walter twin-chamber liquid-fuel rocket motor, with the gas generator and turbopump amidships and the vertically paired combustion chambers aft. The fuel tanks held 552 litres (121 Imp gal) of fuel and 1,100 litres (242 Imp gal) of oxidiser. Due to the high consumption of fuel by the rocket motors, this amount was sufficient for a flight of just a few minutes' duration. There was no provision for armament.

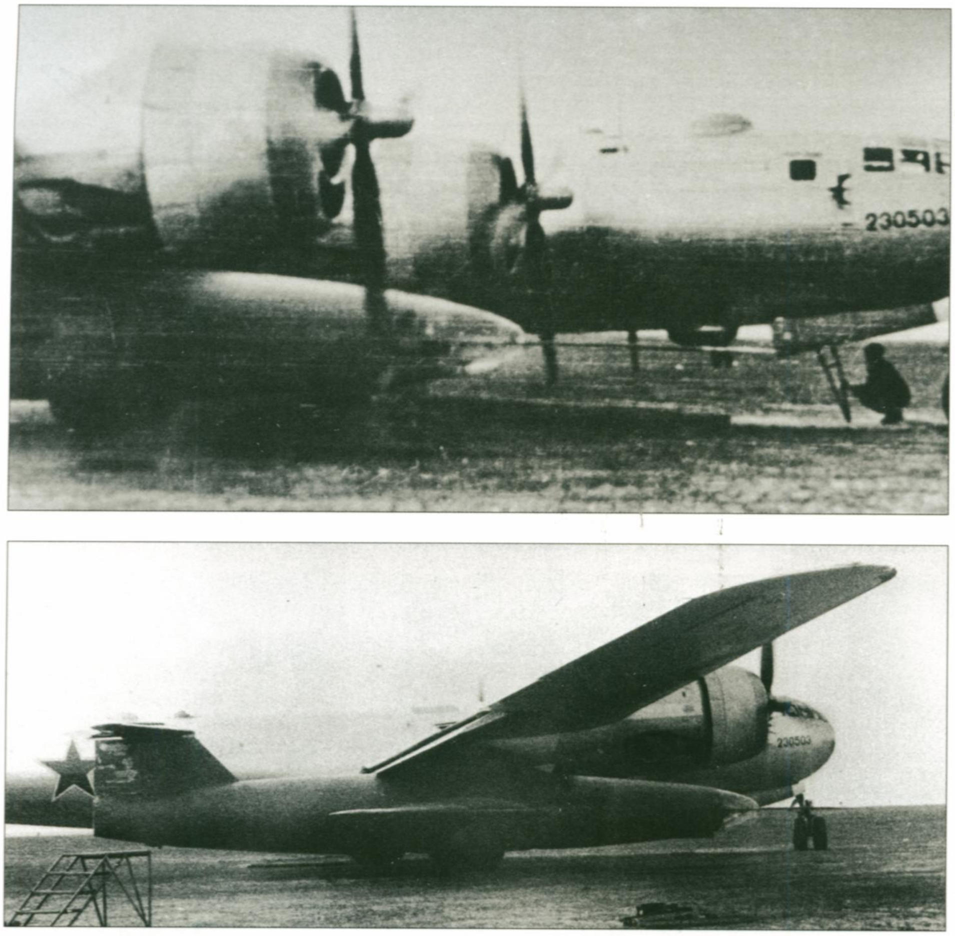
To record the progress of the flight, the employees of the plant's OKB-2 developed an onboard data recording unit intended to capture 36 parameters concurrently. Test benches for the rocket motor were also built at the plant, but it was not before the end of 1947 that it proved possible to obtain fuel for the rocket motor. Testing and development of the powerplant went on throughout the year of 1948.

Preliminary experimental research in TsAGI and LII took some time; therefore the construction of the glider version of the '346' aircraft, known at OKB-2 as the '346-P' (for ***plah**ner* – glider), was not completed before the second half of 1948. It had a simplified design: there was no pressure cabin, engine and fuel tanks, and the use of ballast made it possible to change the weight of the machine. In the course of the flight test programme the '346-P' was used for developing the techniques of disengagement from the carrier aircraft; a check-up was made of the machine's stability and handling at different CG positions, experience was accumulated as regards piloting in a prone position and especially the landings with the use of a skid. The flight testing of the experimental aircraft in the glider version was conducted by Wolfgang Ziese.

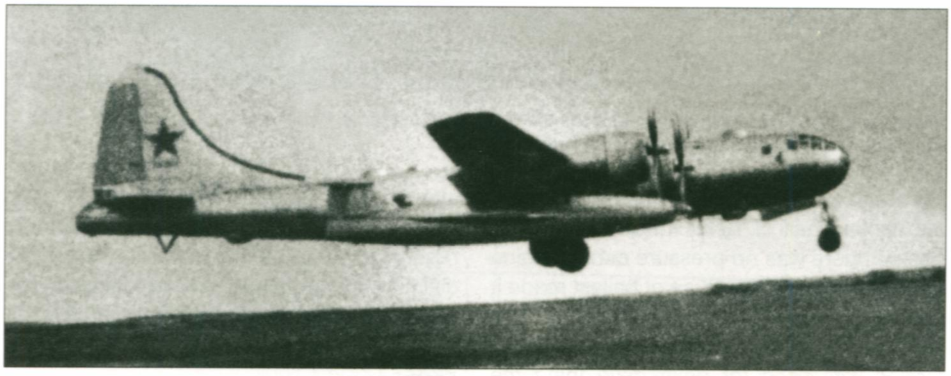
For the purpose of flight-testing the real aircraft it was decided to use a US-built



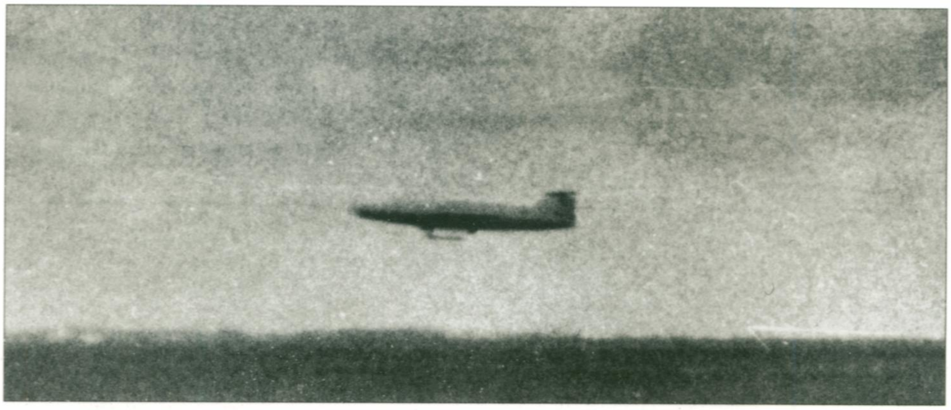
The other carrier aircraft used in the '346' programme was a similarly converted Soviet-built Tu-4 (c/n 230503).



Top and above: Tu-4 c/n 230503 engine running with the '346-3' attached under the starboard wing. The dark colour of the experimental aircraft is noteworthy.



Above: The Tu-4 'mother ship' takes off, carrying the '346-3'.



A poor-quality but rare shot showing the '346-3' as it glides to a landing; the deployed skid is visible.

Boeing B-29 Superfortress bomber as the carrier ('mother ship'). The bomber in question, a B-29-5-BW serialled 42-6256 (c/n 3390), was one of the three Superfortresses that had fallen into Soviet hands not long before the end of the Second World War when they force-landed in the Soviet Far East after suffering battle damage during raids on Japan. A carrier aircraft of Soviet design capable of lifting a suspended load to an altitude of some 10,000 m (32,800 ft) simply did not exist at that time. The bomber was fitted with a special rack under the starboard wing between the engine nacelles for carrying the experimental aircraft. At high altitude the '346' was released and the test pilot performed a gliding descent followed by a landing. On the whole, the testing proceeded successfully.

Despite all efforts to speed up the work of the German designers, it took quite some time to complete the first flyable example of the aircraft incorporating all project modifications. On 5th May 1949 the experimental plant No.1 submitted for flight testing the '346' aircraft on which a rocket motor had been installed, albeit in dummy form (that is, in non-operational condition). In documents it was referred to as the '346-1'.

The whole summer period and September were used for preparing the '346-1' (346 V1) for testing at an airfield in Tyoplyy Stan south of Moscow (the area is now part of the city and the airfield has been closed down and redeveloped). The first flight took place on 30th September 1949, with Wolfgang Ziese as the pilot. The aircraft, weighing 3,145 kg (6,935 lb), was suspended under the wing of the B-29, which was piloted by A. A. Yefimov and N. A. Zamyatin.

The release took place at 9,700 m (31,820 ft). Immediately it came to light that the aircraft had some handling deficiencies; these had also been manifest on the '346-P' glider, but the pilot did not consider them to be dangerous at that time. On the '346-1' the situation proved to be different – in certain flight modes it was impossible to manoeuvre the aircraft. With much effort, the pilot succeeded in keeping the aircraft under control. However, he misjudged the landing approach, and the aircraft landed at a speed which was higher than calculated (some 310 km/h, or 193 mph). After the first touchdown the '346-1' bounced to a height of 3-4 m (10-13 ft) and flew a further 700-800 m (2,300-2,625 ft). During the second touchdown the skid retracted on impact, and the aircraft slid along the runway on its belly until it came to a standstill. The pilot's berth and harness proved unreliable, too. During the abrupt deceleration after the landing Ziese was thrown forward, hitting his face against the forward transverse beam in the cabin, and was knocked unconscious. Fortunately, the pilot's injuries proved to be minor, and after some treatment in a hospital he returned to his duties. The machine, too, suffered only superficial damage.

A commission headed by test pilot N. S. Rybko was set up for investigating the causes of the accident. The commission came to the conclusion that the accident had been caused by incomplete extension of the skid. The document on investigation results stated: *'The incomplete extension of the skid during the flight was due to only one possible cause: the incorrect actions of pilot Ziese who had failed to push the button connected to the skid extension lever firmly enough. As a result, the lever of the winch failed to engage, and the skid failed to lock in the extended position'.* One might add that due to the unexpected control problems the pilot must have concentrated entirely on piloting the aircraft, which is exactly why he had failed to push the said button firmly enough.

The damaged aircraft was repaired, undergoing some modifications in so doing (including changes to the control system), whereupon it was transferred to LII. While Ziese was receiving medical attention, pilot P. I. Kaz'min continued testing the '346-1'. In his flights the main attention was given to the aircraft's handling qualities. The rocket motor was not ignited. On his very first flight in the '346' the skid failed to lock down again, but this time the machine landed on a snow-covered field and the incident ended without trouble, the '346-1' suffering virtually no damage. Some time later Kaz'min made the second flight, in which the '346-1' was towed by a Tu-2 to an altitude of 2,000 m (6,560 ft) and then cast off to make a free flight. Again the landing was unsuccessful because the pilot undershot – damaging the aircraft this time. More repairs ensued.

Nevertheless, on the whole the testing proceeded successfully, except on one occasion when Ziese forgot to check the position of the ailerons before the aircraft parted company with the 'mother ship'. As a result, the '346-1' ('346 V1') flipped inverted, and the pilot barely managed to bring the aircraft into a level attitude.

The results of the early flights provided the basis for the 'Report on the flight tests of the '346' aircraft'. Some excerpts from this report quoted below will be of interest for the reader.

This calls for some explanation, lest the reader should be confused by the designations applied to the German rocket-propelled aircraft in Soviet documents quoted further on. In the said Report, which was endorsed on 28th October 1949, one can see the designations '346A', '346B' and '346D'. In the author's opinion, the designation '346A' refers to the glider version of the aircraft (previously referred to as the '346-P'), the designation '346B' denotes the '346-1' version and the designation '346D' refers to the modified (*dora**bot**annyy*) first flyable example, the '346-1', with an operational rocket motor.

Report on the Flight Tests of the '346' Aircraft

(Stage 1 of the programme)
Endorsed on 28.X.49
Tests performed by:
test pilot Yefimov;
test pilot Ziese;
project engineer Molochayev.

A Summary of the Test Programme

Tests have been conducted of the '346A' glider, dimensionally identical to the '346B' airframe and tests of the '346D' without igniting the [rocket] motor. In the course of the testing, techniques were developed for the carriage of the '346D' aircraft by the 'mother ship', as were the release of the '346D' and its landing. A qualitative evaluation of the '346D' aircraft's piloting qualities in a glider version has been obtained.

The purpose of the tests.

The flight tests of the '346' aircraft pursued the following purposes:

1) developing techniques of carrying the '346' aircraft underneath the 'mother ship' No.256;

2) developing techniques of the release of the '346' aircraft by the 'mother ship';

3) checking the stability of the '346' aircraft in free flight with various CG positions;

4) checking the aircraft's handling with retracted skid and without underwing skids;

5) developing techniques of landing on the skid without using underwing skids.

Test Results

In the course of the testing, four taxi runs and five flights were made. When the taxi runs showed that the '346' aircraft behaved normally when suspended, the first flight was made. The first three flights involving the carriage and release of the '346' aircraft were performed for the purpose of developing the release procedure. The aircraft's weight in the first three flights was 2,180 kg [4,810 lb], the CG position being at 29.3% MAC. In two flights the release of the '346' aircraft was effected in gliding mode at a gliding speed of 300 km/h [186 mph] and a sink rate of 4 m/sec [787 ft/min]. In one of the flights the aircraft was released at a speed of 350 km/h [218 mph] with a sink rate of 6 m/sec [1,180 ft/min]. After that it was established that the release was best performed at 300 km/h and a sink rate of 4 m/sec. In the fourth flight the weight of the '346' aircraft was 1,880 kg [4,154 lb], the CG position being at 27% MAC. In one of these flights the pilot failed to check the position of the ailerons before disengagement from the 'mother ship'; as a result, immediately after the release the aircraft flipped over, losing nearly 2,000 m [6,560 ft] of altitude before it could be brought into gliding flight. In the fifth flight the '346' aircraft was carried with the rocket motors installed, but these were not ignited. The flight weight was 3,145 kg [6,930 lb], the CG being at 27% MAC. The aircraft was released at an altitude of 9,700 m [31,825 ft]. In this flight it was established that the elevators of the '346' aircraft had no aerodynamic balance, while the ailerons were overbalanced. For these reasons it was impossible to make any changes of the aircraft's attitude at speeds in excess of 300 km/h. When the landing skid was extended, it failed to lock down. At the moment of touchdown at an excessively high speed of 300 km/h the skid retracted, the aircraft suffering minor damage.

The 'mother ship' was piloted by A. A. Yefimov and N. A. Zamyatin; the '346' was piloted by Ziese.

Conclusions

1) Techniques have been developed for the carriage and release of aircraft '346' by aircraft No.256;

2) A qualitative assessment has been made of the '346' aircraft's stability and handling at CG positions of 29% and 27% MAC.

3) The functioning of the onboard data recording unit has been verified.

(signed) Project engineer of LII
V. Ya. Molochayev
25.10.49

Conclusion:

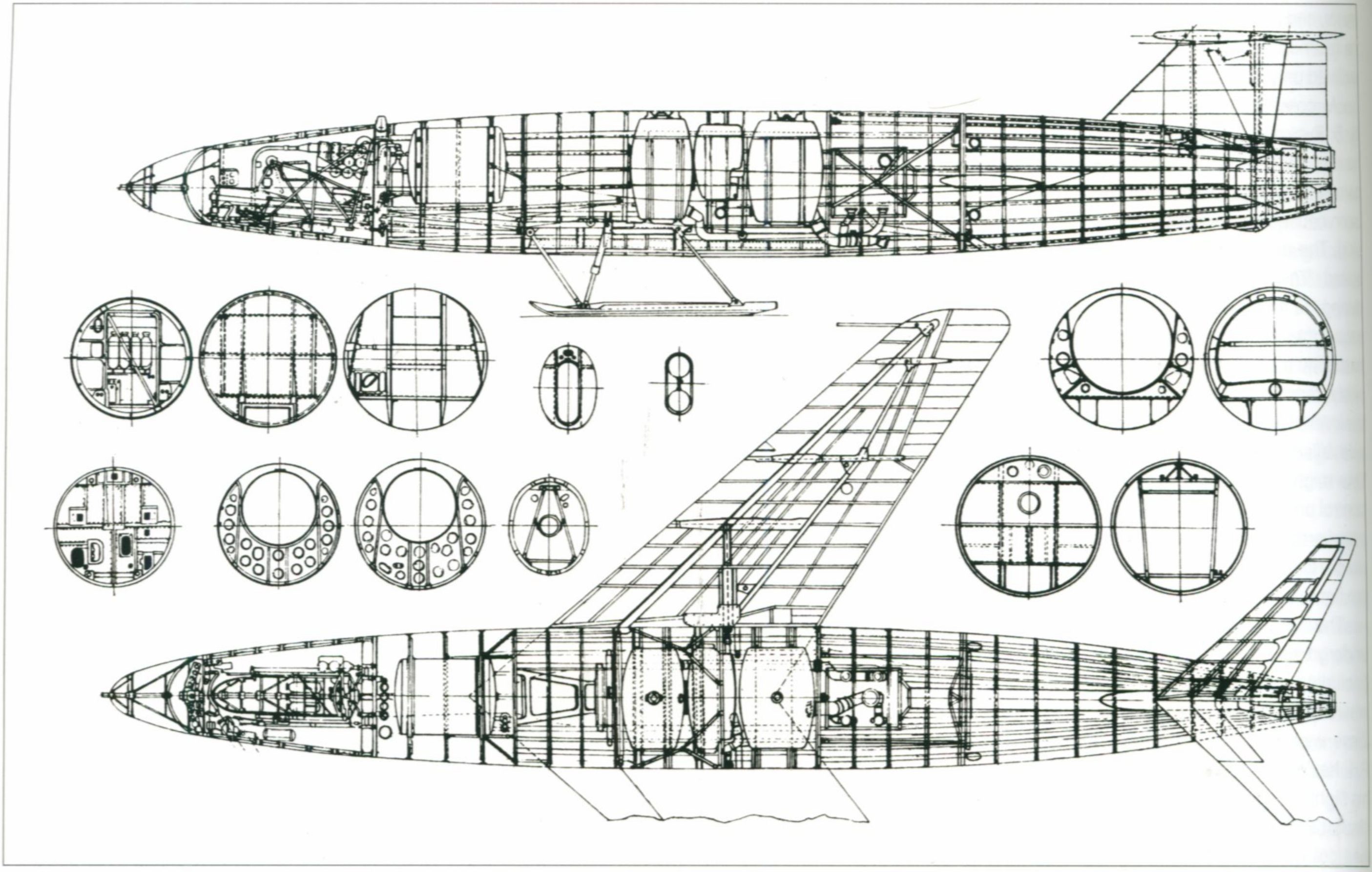
1) It is recommended that after the inspection of the '346' aircraft the flying personnel of LII should take training.

2) Testing of the aircraft (after repairs) should continue in the powered version in accordance with the approved programme.

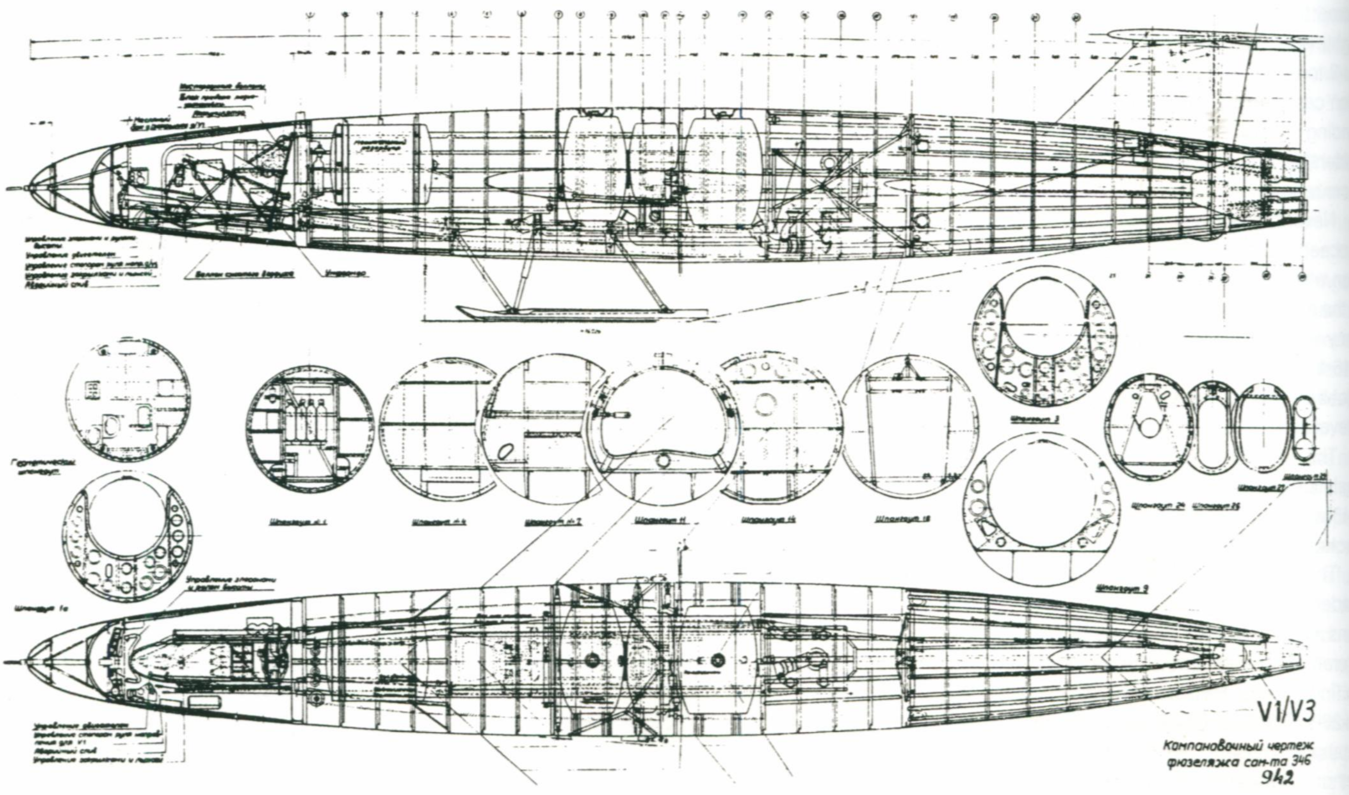
(signed) Deputy chief of facility No.1 Kvitko

(Note: The mysterious 'aircraft No.256' mentioned here is the aforementioned B-29-5-BW c/n 3390 whose original USAAC serial, 42-6256, had been amended to '256 Black' when Soviet insignia were applied. Stating the proper designation of this aircraft in Soviet documents was out of the question because the fact of its existence in the USSR was top secret. Moreover, in some copies of the abovementioned report (such documents were usually typed out in six copies) the serial '256' was altogether smeared out with ink or scrubbed out, which testifies to the top-secret status of the American 'booty' – *Auth.*)

A total of 29 flights were performed in Tyoplyy Stan on the '346-P' ('346A') and '346-1' in 1948-49; these included 24 flights of the '346-P ('346A') on tow behind a B-25, four flights of the '346-P' ('346A') in a suspended position under the B-29 and one flight of the



Above: A drawing giving details of the internal structure of the '346-3'. Note the lightening holes in some of the bulkheads.



Фиг. 17

A similar drawing from the aircraft's Soviet manual enumerating the fuselage frames and naming some of the equipment items. This was probably a German drawing of the first prototype with amendments made in the Soviet Union to show the changes made on the second prototype.

'346-1' ('346D') with the motor installed, but not running. The test pilots and engineers concluded that the experimental aircraft's piloting properties were generally satisfactory and that it was possible to commence the main part of the test programme involving powered flights. For this purpose the second prototype was prepared, with the rocket motor already installed; it received the designation '346 V3' or '346-3'. Its assembly was completed in May 1950. The '346-3' differed from the '346-1' in having a horizontal tail with greater sweepback and a thinner airfoil (9% instead of 12%) and in having no landing flaps. The vertical tail was also made thinner (likewise with a thickness/chord ratio of 9%). Nevertheless, an attempt to enhance the ailerons' effectiveness under the conditions of a shock stall proved unsuccessful, and TsAGI imposed a stringent never-exceed speed (V_{NE}) limit: Mach 0.8 for the '346-1' and Mach 0.9 for the '346-3'.

A new factory airfield was built specifically for the purpose of testing the '346-3' at a location some 100 km (62 miles) south-east of Moscow, near the town of Lookhovitsy (the airfield was called Tret'yakovo). Construction work, manufacture of test equipment and transportation of the hardware to the new place took several months. In the meantime, ground runs of the powerplant were conducted on the '346-3'. The fuel used was a mixture of hydrazine hydrate with methyl alcohol and water, 82% hydrogen peroxide being used as the oxidiser.

In early 1951 Wolfgang Ziese, who had recovered from his injuries, started training flights in the '346-P' ('346A') glider, and on 6th April he made the first flight in the '346-3' without igniting the rocket motor. Interestingly, it was only at the initial stage of the tests at Lookhovitsy-Tret'yakovo that B-29 '256 Black' was used as the 'mother ship'; further on it was replaced by its Soviet analogue – a Tupolev Tu-4 bomber manufactured by the aircraft plant No.23 in Fili near Moscow (c/n 230503; the aircraft had no serial).

On 10th May 1951 Ziese made a flight in the '346-1', and on 16th June he performed the first flight in the '346-3'. In both flights, which ended well, the rocket motor was not ignited. Bearing in mind the strict speed limits imposed, it was decided to use only one combustion chamber during powered flights, gradually increasing the amount of fuel.

On 15th August Ziese ignited the engine in flight for the first time. Due to maximum speed limitations only one chamber of the rocket motor was used; the maximum thrust of the engine reaching 1,570 kgp (3,530 lbst) on that occasion. The powerplant was ignited at an altitude of 7,000 m (22,960 ft) in 1 minute 40 seconds after the separation from the carrier aircraft. The rocket motor ran for 1.5 minutes, followed by a gliding flight and landing.

The flight turned out to be a sore trial for the pilot. During powered flight strong lateral instability was experienced, and Ziese constantly had to roll the aircraft level by applying ailerons. To make matters worse, because of the poor functioning of the heating regulator the cockpit temperature rose to +40ºC (+104°F), and flying the aircraft in these conditions was extremely difficult. Ziese said later that he was on the point of fainting. In compensation for all the suffering, however, Ziese received a reward of 20,000 roubles for the first powered flight in the '346' – quite a bundle by the day's standards.

In all, Ziese made three powered flights in the '346-3'. After the installation of ventilation valves in the cabin the following flight took place on 2nd September and passed quite uneventfully, but the third flight with the rocket motor running, performed on 14th September, ended in an accident. In that flight the fuel amount was 60% of the maximum. The aircraft was released from the 'mother ship' at an altitude of 9,300 m (30,510 ft). The rocket motor was fired up at an altitude of 8,500 m (27,880 ft) and the '346-3' started climbing rapidly. At first the pilot maintained a constant airspeed by increasing the climb angle, but then the speed started growing. At an altitude slightly in excess of 12,000 m (39,360 ft) the speed exceeded 950 km/h (590 mph) and the aircraft lost lateral controllability, performing, as the pilot reported, a spontaneous flip. The machine started rolling uncontrollably. Some time later the pilot regained control and managed to put the aircraft into a dive. As it recovered from the dive at an altitude of some 7 km (22,960 ft), the aircraft started rolling again. The pilot came to the conclusion that he would not be able to cope with the aircraft before he ran out of altitude. He decided to bail out and detached the pressurised cockpit by detonating the explosive bolts. In all, the free flight of the '346-3' had lasted just over three and a half minutes.

For about ten seconds the cockpit section fell, tumbling every which way; then the stabilising parachute deployed automatically, and the cockpit entered a smooth descent in a nose-down attitude, revolving at a rate of one revolution per second. At an altitude of about 3 km (9,840 ft) the pilot was ejected together with his berth and the Perspex nosecone of the cockpit. During the descent the nosecone went upwards, the pilot easily detached himself from the berth and used his own parachute, landing safely.

Since all the data recording equipment was destroyed together with the '346-3' aircraft, the cause of the crash was never established with certainty. According to one suggestion voiced by the 'tin kickers' investigating the crash, the aircraft started rolling uncontrollably when it exceeded the V_{NE} imposed by TsAGI and the ailerons lost their effectiveness. During the dive the aircraft went supersonic, the shock stall was left behind and the '346-3' regained controllability. After the shutdown of the rocket motor and the ensuing recovery from the dive the speed began to bleed off, the aircraft re-entered the transonic speed area and again lost lateral control; it began to fall, tumbling crazily, hit the ground and was destroyed by the post-crash fire.

After this accident the work on the '346' aircraft was terminated. Yet another 'Report on the flight tests of the '346' aircraft' contained the following conclusion:

'Despite the accident involving the "346" aircraft, it must be considered that the purpose of the testing, with due regard to speed limits, has been achieved and the tests that have been conducted have shown:

1) good, reliable operation of the liquid-fuel rocket motor, both during ground tests and in flight on the "346" aircraft; reliable ignition of the motor, using hypergolic propellants, at high altitude;

2) impeccable functioning of the rescue system, which was ensured on the "346" aircraft by separating the pilot's pressurised cockpit from the fuselage, with the subsequent ejection of the pilot at low speeds that had been tried out both during the accident and during preliminary tests;

3) the possibility of piloting an aircraft in a prone position which permits the pilot to sustain considerably higher loads on his organism in comparison with the conventional position;

4) the feasibility of landing an aircraft fitted with a skid landing gear on an unprepared natural ground airfield at speeds of up to 330 km/h [205 mph];

5) a high rate of climb at all altitudes and the ability of rocket-propelled aircraft to accelerate rapidly;

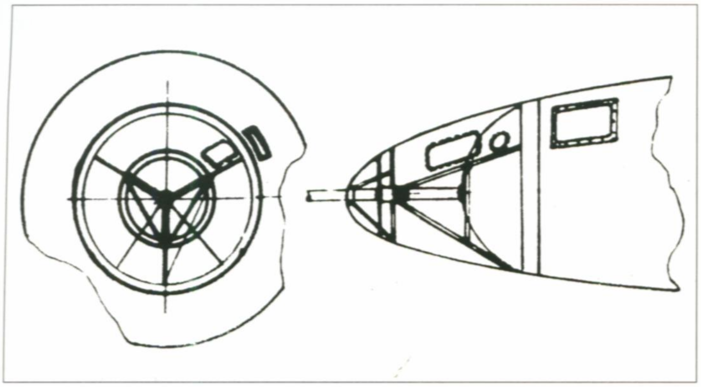
6) satisfactory operation of all the hardware.

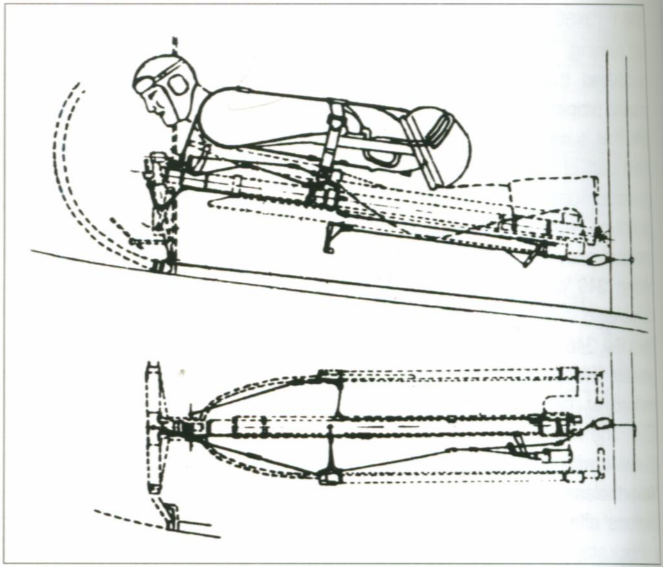
Despite the positive results obtained, further testing of the remaining flyable example (the "346-1" aircraft) is inexpedient for the following reasons:

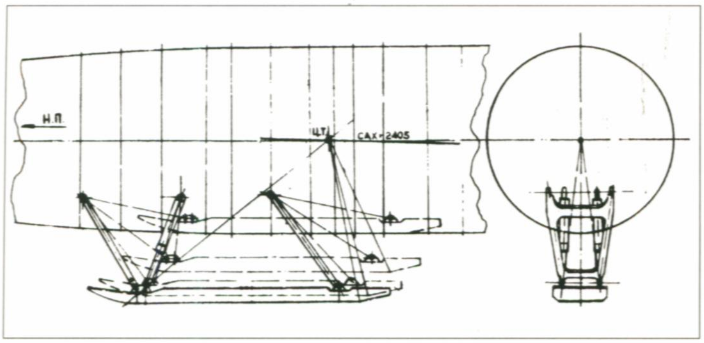
1) Further flights of the "346" aircraft cannot yield substantial results.

2) The remaining first flyable example of the "346" aircraft has a lower speed limit (Mach 0.8) as compared with the example that was lost in the accident (Mach 0.9).

3) Aerodynamic refinement of the remaining example for the purpose of lifting the speed restrictions is inexpedient due to the ageing of the airframe which has been in open-air storage for a long time and cannot guarantee the safety of eventual further flight testing.'



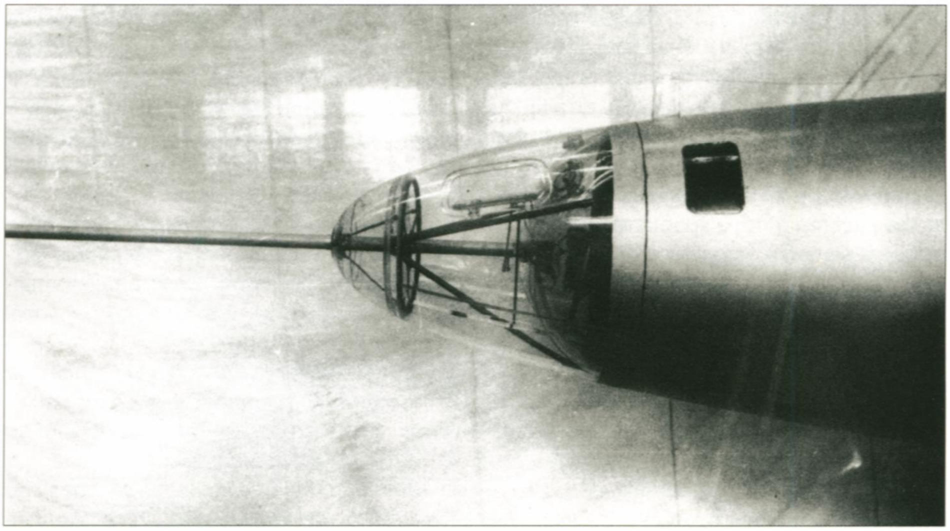




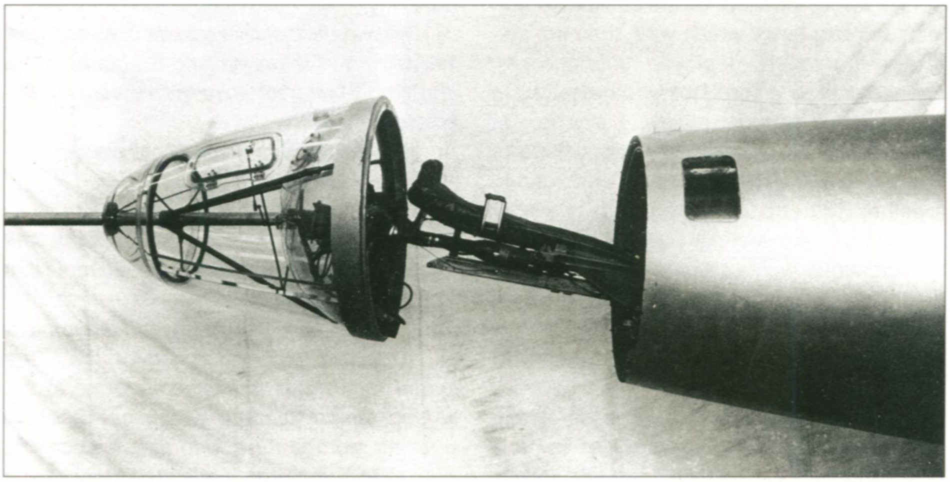
Above: The pilot's berth and flight controls of the '346', with a low-set control stick and aft-mounted rudder pedals.

Above left: Details of the 346's cockpit canopy/pressure dome assembly.

Left: The main landing skid in no-load, ground static and retracted positions.



Above: The cockpit canopy in the closed position. The transparent forward pressure dome and the bracing struts of the centrally mounted pitot boom are visible through the parabolic nose fairing.



The cockpit canopy slid forward into the fully open position together with the pilot's berth. The rectangular cover in the nose fairing is a maintenance access door, not a direct vision window.

Since the aircraft attained a speed in excess of 900 km/h (559 mph) when using less then half the maximum available thrust, one can surmise that with both chambers ignited it would have been able to exceed the speed of sound. However, taking into account the insufficiently perfected aerodynamic layout, the designers refrained from the risk of undertaking such a test.

Thus, between 12th October 1950 and 14th September 1951 a total of 19 flights was performed in Lookhovitsy; these included 12 flights of the '346-P' glider on tow behind a captured Junkers Ju 388 acting as towplane, two flights of the '346-P' glider suspended beneath a bomber, one flight of the first prototype, the '346-1' ('346D') with engines inoperative, one flight of the second prototype, the '346-3', with motors inoperative and three powered flights of the '346-3'.

In the course of the tests the following performance of the '346' aircraft was obtained: a maximum altitude of 12,000-13,000 m (39,370-42,650 ft), a maximum speed of 950 km/h (590 mph), a maximum Mach number of 0.9-0.95 in level flight, a maximum climb rate of 100 m/sec (19,680 ft/min). The diving speed in the last flight with the rocket motor turned on was presumed to be supersonic.

The development of the '346' experimental aircraft became the most costly programme of the experimental plant No.1. As can be seen from documents, 55 million roubles were spent on this programme between April 1946 and September 1951, which was an exorbitant sum for that period, even by the standards of the Soviet aircraft industry which was receiving heavy investments.

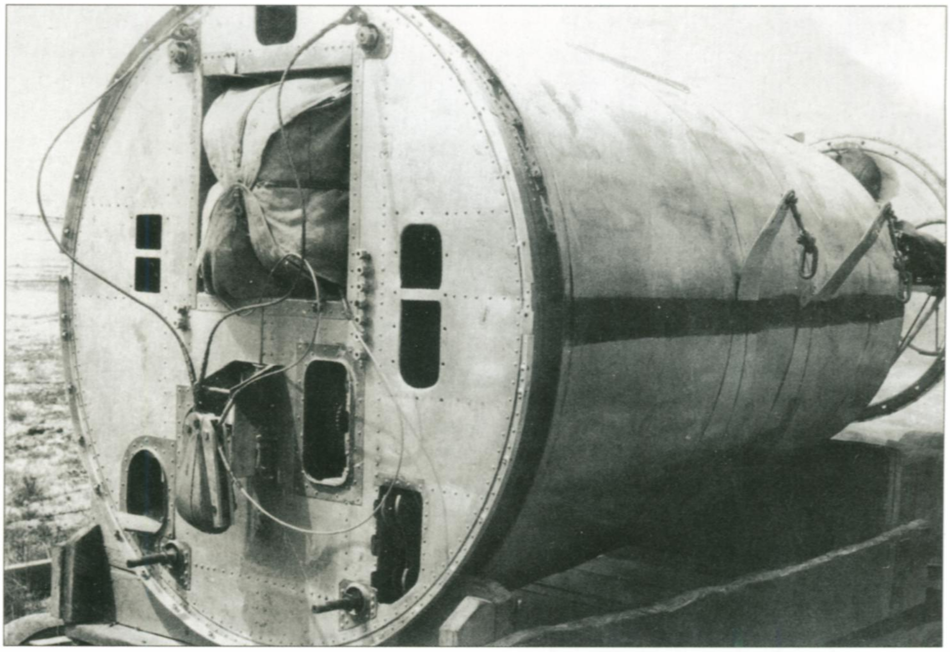
Right: The detachable cockpit section of the DFS 346 seen from the rear, showing the packed stabilising parachute and the four explosive bolts attaching the cockpit section to the rest of the airframe. This example was dropped from LII's B-25J during tests of the rescue system, hence the attachment straps/lugs on the sides.

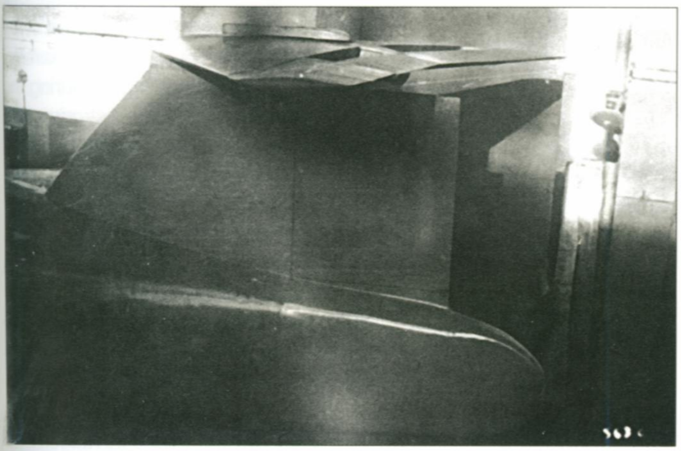
Below: The tail unit of a model of the DFS 346 V1 tested in TsAGI's T-106 supersonic wind tunnel. Note the fairing replacing the actual cut-off rear end with the rocket motor nozzles.

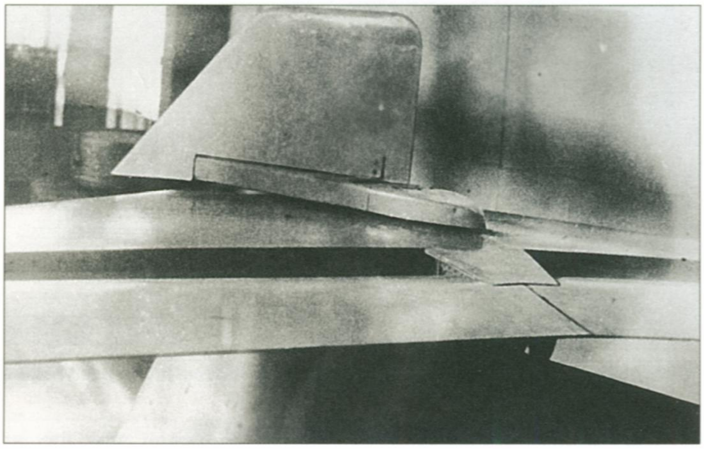
Below right: The *Paddel* control surface on the top of the wind tunnel model's fin replicated the one seen on the actual DFS 346 V1 when first tested in the T-101 wind tunnel.

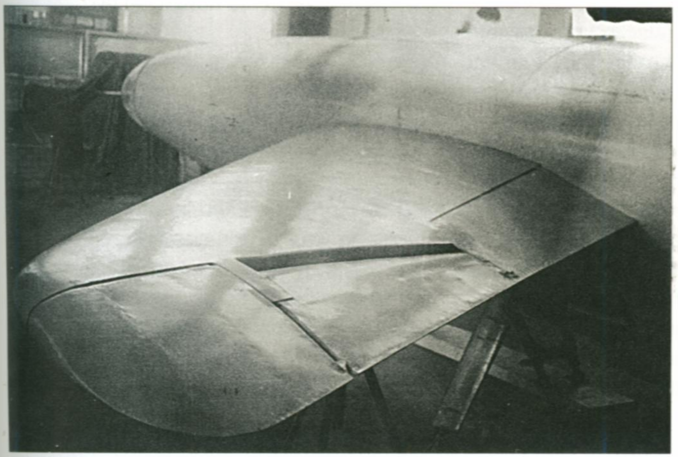
Bottom: The port two-section aileron of the full-size '346-1' set neutral, with the port flap inboard of it.

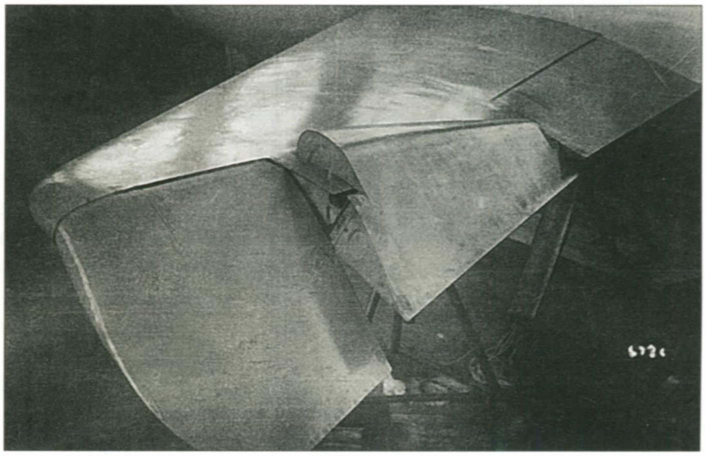
Bottom right: The port aileron at maximum deflection; note the aerodynamic balancing of the inboard section.









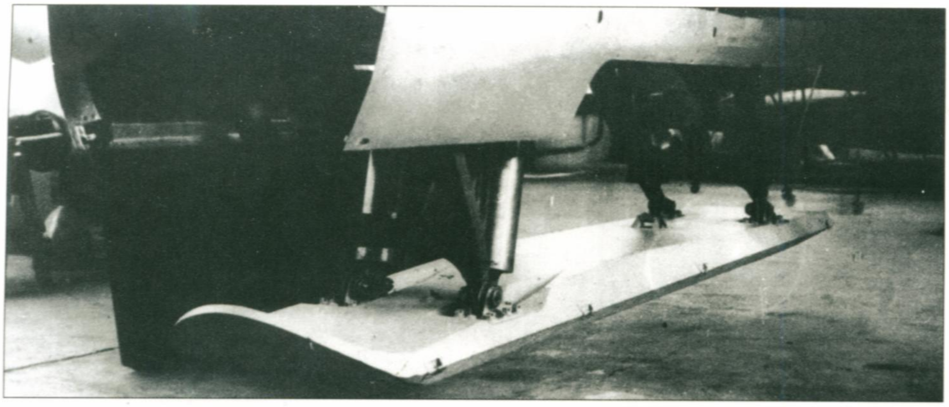


Interestingly, some time after the completion of the test programme Chair 101 of the Moscow Aviation Institute (MAI) received an example of the '346' aircraft with a modified tail unit for use as an instructional airframe. Since we know that the second prototype featuring such a tail unit had crashed, one may surmise that the institute received the '346-P' glider variant which, judging by the 1949 test report, was dimensionally identical to the '346B' machine (that is, the higher-speed version of the aircraft).

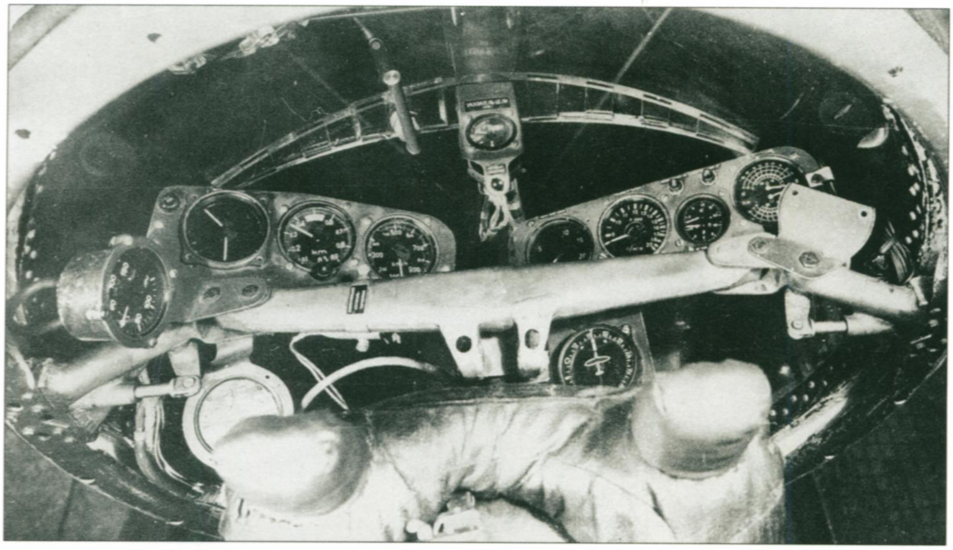
The '346' Aircraft in Detail

Type: Single-seat high-speed research aircraft. The airframe was almost entirely of riveted duralumin construction.

Fuselage: The aircraft's fuselage was cigar-shaped and featured a high fineness ratio of 8.3. The maximum diameter was 1.62 m (5 ft 1 in), the length was 13.45 m (44 ft 1½ in). The fuselage consisted of three main parts joined by bolts. The metal framework of the fuselage consisted of duralumin frames and stringers; these were riveted to stressed skin panels, also made of duralumin.



Above: The main landing skid of the first prototype. Note the cutouts in the skid bay doors suggesting that the doors were to close, once the skid had been extended.



The instrument panels of the '346'. The object at the bottom is a padded headrest.

The *forward (nose) section* was an axisymmetrical body with a contour formed by the NACA 00121-0,66-50 airfoil. It was followed by a cylindrical section and by the aft section whose cross-section smoothly changed from circular to elliptical with the larger axis vertical. The nose section had a glazed front fairing with a braced pitot boom mounted at its extremity. The nose fairing had double Perspex glazing, the outer glazing being of parabolic shape and the inner one (the pressure dome) of hemispherical shape.

The forward fuselage accommodated a pressurised cockpit, which had a wooden framework. The pilot lay prone on a special berth which slid forward together with the cockpit glazing for access. The cockpit section was attached to the fuselage by four explosive bolts; in an emergency it could be jettisoned by detonating the bolts. The cockpit section was separated from the rest of the fuselage by a pressure bulkhead. Attached to the latter from behind was a drag parachute used to stabilise the cockpit section in an emergency after the latter's separation from the fuselage. The pilot's berth was provided with an device which ejected him from the cockpit after the latter had detached itself from the fuselage in an emergency.

The *centre fuselage* (also an axisymmetrical body) was occupied entirely by fuel and oxidiser tanks. A small recess was provided for the landing skid using a parallelogram retraction mechanism and another for a beam carrying the attachment points for the port and starboard wings. The centre fuselage also housed strain gauges for monitoring the wing stresses and the test equipment package with data recorders.

The *aft fuselage* housed a small amount of fuel, as well as turbopump units for the fuel feed and the two chambers of the liquid-fuel rocket motor.

Wings: Cantilever all-metal two-spar construction of swept-back planform with rounded tips; sweepback at quarter-chord 45°. The wings featured NACA-0,012-0,55-1,25 airfoils along the entire span, with a thickness/chord ratio of 12%. The wing area was 19.87 m^2 (213.9 sq ft). Two boundary layer fences were installed on the upper surface of each wing. The wings were fitted with hinged landing flaps, plus two-section ailerons whose chord increased towards the wingtips. The ailerons consisted of outboard and inboard sections mechanically linked to each other; the gearing ratio between them could be changed by the pilot. At low speeds all the sections of the ailerons deflected to the same angle, while at high speeds only the outboard sections were to be deflected (during the testing the gear ratio from the control wheel to the outboard ailerons was made twice higher than the gear ratio to the inboard ailerons.

Tail Unit: Cantilever all-metal T-tail. The swept-back *horizontal tail* incorporated two-section elevators of similar design to the ailerons, the deflection angle being –2°40' to +2°. The two sections of each elevator deflected to different angles in similar fashion to the ailerons. The trapezoidal vertical tail featured a one-piece rudder augmented by a small movable surface above the stabilisers - the so-called *Paddel* ('paddle' in German). At small rudder pedal inputs the deflection of the rudder was produced by the lateral aerodynamic force arising on the *Paddel* during the latter's deflection. In the case of strong pedal inputs they were applied directly to the rudder. In the course of further work the *Paddel* was deleted.

The first prototype ('346-1') had a rectangular rudder and a horizontal tail with 40° sweep at quarter-chord. On the second prototype ('346-3') the fin's area was increased, the rudder became longer and received a noticeable taper, the stabiliser sweepback at quarter-chord was increased to 45°. At the same time the elevator area was reduced, as was the taper of the horizontal tail.

Landing Gear: Since there was no need for independent take-off from an airfield, the undercarriage was limited to a skid retracting aft into the fuselage and closed by twin doors.

Powerplant: Mounted in the rear part of the fuselage was a twin-chamber Walter liquid-fuel rocket motor, delivering a total thrust of 3,740 kgp (8,250 lbst) at sea level and 4,000 kgp (8,820 lbst) at altitude. The overall amount of fuel (kerosene), oxidiser (nitric acid) and catalyst (hydrogen peroxide) was 1,900 kg (4,190 lb). It was sufficient for two minutes' running of the rocket motor at full thrust. To save fuel, only one combustion chamber was ignited during the tests.

Supersonic Interceptor with a Multi-Chamber Liquid-Fuel Rocket Motor ('466', '468' and '470' Projects)

In the late 1940s and early 1950s several project versions of a supersonic interceptor featuring a tailless layout with low-aspect-ratio delta wings were developed by OKB-2 of plant No.1 under the direction of Siegfried Günther, a former designer of the Heinkel company, and Aleksandr Ya. Bereznyak, deputy Chief Designer of OKB-2. A more powerful multi-chamber liquid-fuel rocket motor was envisaged as a powerplant for the fighter. The take-off was to be performed with the help of a dolly, the fighter subsequently landing on a skid. The projects had the factory designations *'izdeliye* (article) 466', *'izdeliye* 468' and *'izdeliye* 470'.

Models of the '466' and '468' were manufactured for wind tunnel tests. As for the '470' version of the project, its development was conducted already with due regard to the results of these wind tunnel tests.

The '470' aircraft was an interceptor with a multi-chamber liquid-fuel rocket motor. The aircraft had a tailless delta layout with low aspect ratio wings and vertical tail surfaces comprising a central fin and two underwing fins. The wing trailing edge was occupied by ailerons and elevators. The landing gear comprised a front skid and two main skids accommodated in the underwing fins. The aircraft was to take-off with the help of a special dolly or sled fitted with solid-fuel rocket boosters, or with the help of a jettisonable undercarriage (no boosters were used in this case), making use of its own skids for landing.

The interceptor was to be powered by a four-chamber liquid-fuel rocket motor, which was then under development at the same OKB-2. According to calculations, the overall thrust of the motor was to be 8,376 kgp

Dimensions of the '346' Aircraft

Length overall, including pitot:	
'346-1'	15.81 m (51 ft 10½ in)/15.987 m (52 ft 5½ in)*
'346-3'	16.55 m (54 ft 3½ in)/16.387 m (53 ft 9 in)*
'346-P'	16.355 m (53 ft 8 in)*
Length less pitot	13.45 m (44 ft 1 in)/13.642 m (44 ft 9 in) for the '346-1'
Fuselage length	13.25 m (43 ft 5½ in)
Height on ground	3.25 m (10 ft 8 in)/3.030 m (9 ft 11 in)*
Fuselage cross-section area, m² (sq ft)	2.06 (22.18)
Wing span	9.005 m (29 ft 6½ in)
Gross wing area, m² (sq ft)	19.87 (213.9)
Net wing area, m² (sq ft)	14.87 (160.07)
Wing centre section area (inside fuselage), m² (sq ft)	5.00 (53.82)/5.07 (54.58)*
Horizontal tail span, m (ft)	3.6 (11 ft 9 ¾ in)
Horizontal tail area, m² (sq ft):	
'346-1'	3.8 (40.9)
'346-3'	4.02 (43.28)
Vertical tail area, m² (sq ft)	3.85 (41.44)
Fin area (less rudder), m² (sq ft)	2.158 (23.23)
Rudder area, m² (sq ft):	
'346-1'	0.8 (8.61)
'346-3'	0.65 (7.0)
Flap area (total), m² (sq ft)	2.45 (26.37)
Area of each aileron, m² (sq ft):	
Inboard	0.5 (5.38)
outboard	0.4 (4.3)
Elevator area, m² (sq ft):	
inboard	0.44 (4.74)
outboard	0.36 (3,88)

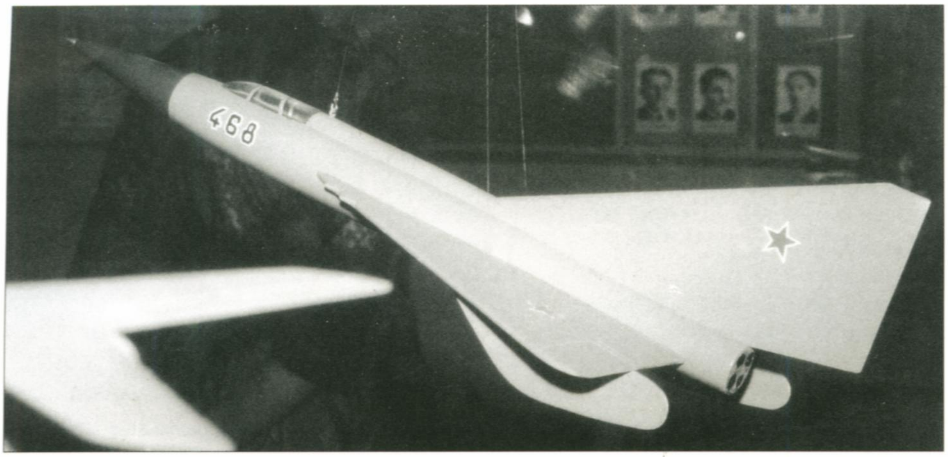
* Different documents give different figures

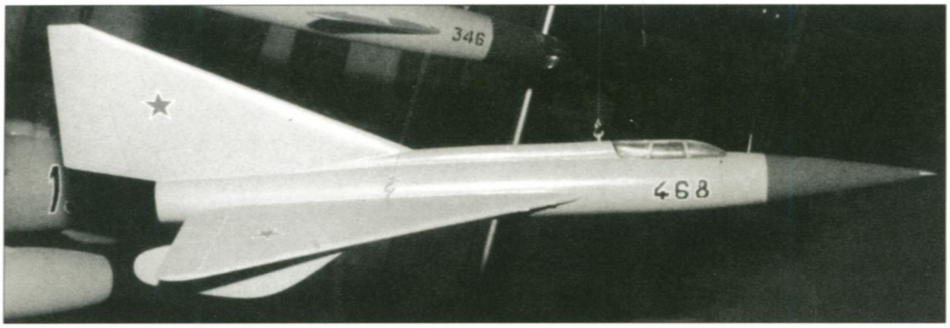
Weights and Take-off Performance of the '346' Aircraft

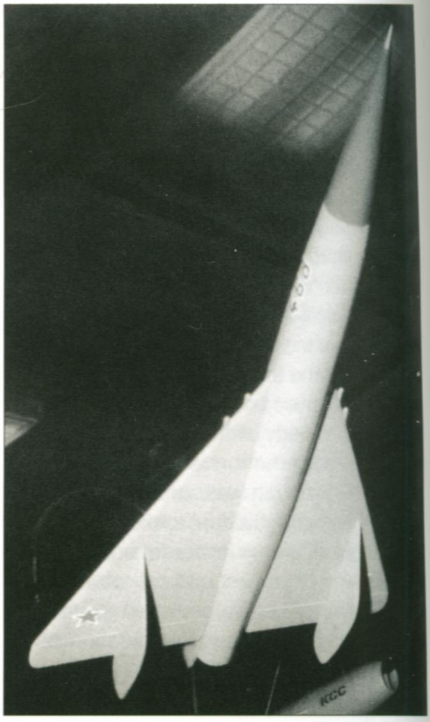
	'346-1' ('346D')	'346-3'	Notes
Empty weight, kg (lb)	2,300 (5,070)	n.a.	
Thrust/weight ratio, kgp/kg (lbst/lb)	0.7	n.a.	
All-up weight, kg (lb):			
in the glider version (without motors)	1,880-2,180 (4,145-4,807)	n.a.	
with motor, but without fuel	3,125-3,145 (6,890-6,935)	n.a.	
maximum (with motor and fuel)	5,260 (11,598)	5,230 (11,532)	
Landing weight (minimum), kg (lb)	3,260 (7,188)	3,320 (7,320)	
Wing loading, kg/m² (lb/sq ft)	265 (54.28)	263 (53.87)	
Engine thrust (single chamber), kgp (lbst)	n.a.	1,570 (3,462)	
Fuel/oxidiser ratio	n.a.	1:2.13	
Maximum Mach number	0.8	0.9	According to limits imposed by TsAGI
Altitude for release, m (ft)	10,000 (32,800)	10,000 (32,800)	Design figure
Speed at the moment of release, km/h (mph)	520 (323)	520 (323)	
Altitude attained, m (ft)	n.a.	12,000 (39,360)	
Rate of climb attained, m/sec (ft/min)	n.a.	100 (19,690)	
Landing speed, km/h (mph)	200 (124)*	200 (124)†	
Engine operation time, sec	–	165	In the last flight

* In accordance with TsAGI-imposed limit with flaps set at 14° and a lift coefficient of 0,8

† In accordance with TsAGI-imposed limit with flaps set at 15° and a lift coefficient of 0,7







Three views of a model of the '468' two-seat interceptor in the city museum in Doobna. Of note are the quadruple rocket motor nozzles, the nose radome, the wing-mounted cannons and the exceptionally large tail. The underwing fins doubled as housings for the main landing skids.

(18,469 lbst) at sea level, rising to 9,830 kgp (9,830 lbst) when the fighter climbed to 20,000 m (65,600 ft).

To ensure the pilot's survival in an emergency, the fighter was to be equipped with an ejection seat; in addition, the use of a high-altitude rescue pressure suit was envisaged. The pilot's cabin was hermetically sealed and provided with an atmosphere revitalisation unit. According to the project, the aircraft was to be provided with a *__Kor__shun* (Kite, the bird) radar, a *__Krem__niy* (Silicone) identification friend-or-foe interrogator/transponder and an OSP-48 instrument landing system (*obo__roo__dovaniye sle__poy__ po__sahd__ki* – blind landing equipment).

Three armament options were envisaged. The first one included four 23-mm (.90 calibre) Shpital'nyy Sh-3 cannons with an ammunition complement of 90 rounds per gun; another was armed with two ORO-132 automatic three-tube rocket launchers holding six 132-mm (5.19-in) TRS-132 rocket projectiles, while the third option was a strike version with four FAB-50M9 high-explosive bombs and a bombsight ensuring accurate delivery. Of these, the cannon-armed version received the most detailed treatment in the advanced development project.

The aircraft's armour plating provided protection for the pilot in the forward hemisphere (from the front and from below). It comprised a 110-mm (4$^{21}/_{64}$ in) bulletproof windscreen, a front armour plate of 16 mm (0$^{5}/_{8}$ in) thickness and a lower armour plate 8 mm (0$^{5}/_{16}$ in) thick.

The 'Conclusion on the ADP of an interceptor powered by a liquid-fuel rocket motor (manufacturer's designation '470'), signed by Lieutenant-General of Engineering and Technical Service Volkov (acting chief of the Air Force's Aircraft Materiel Committee) and endorsed by Major-General of Engineering and Technical Service Shishkin (deputy Commander of the Air Force for prototype aircraft construction) contained the following remarks from the military. These may be of interest for the reader wishing to get a clearer idea about this project, which was quite a departure from the usual Soviet aircraft construction practices, and about the reaction of the military to this project:

'1. The aerodynamic layout and structural design of the aircraft with low aspect ratio delta wings ensures flight at speeds up to Mach 1.8 and raises no objections. Delta wings without a horizontal tail have a lifting capacity inferior to that of wings fitted with high-lift devices and combined with a horizontal tail. However, delta wings without a horizontal tail can have greater area and a relatively lower weight than swept-back wings.

2. The project materials contain a sufficiently detailed study of the optimum airfoil for this aircraft. More that 70% of the total amount of fuel is used for climbing to an altitude of 22,000 m [72,160 ft]. The endurance and range in level flight at a given altitude is determined by the amount of fuel remaining after the climb to this altitude. Therefore it is necessary to make additional calculations for level flight at altitude, analysing possible deviations in the motor operation modes and in the take-off mode, for the purpose of determining the influence of these deviations on the range.

3. One of the project's strengths is that that much attention has been paid to the aircraft's stability and handling. However, the static stability and controllability characteristics need to be explored and checked by testing models of the aircraft in a wind tunnel. It is also necessary to determine by calculation the dynamic characteristics and to study, in relation to high altitudes, the character of minor longitudinal and lateral oscillations, their frequency and damping, and the character of the aileron input when banking the aircraft and levelling it out again.

4. The aircraft's range and endurance are determined on the assumption that the fuel is consumed fully in level flight. The fuel reserves necessary for performing an instrument landing making use of the OSP-48 equipment have not been taken into account in the calculations.

5. The wing span chosen when defining the configuration of the aircraft is undersized. With the landing weight of some 4,500 kg (9,920 lb) the specific wing loading is as high as 90 kg/m^2 [18 lb/sq ft], whereas for modern fighters it is just about 40 kg/m^2 [8 lb/sq ft]. This makes the landing more difficult.

6. The sink rate during the landing approach has been calculated for the config-

uration with the landing gear retracted, and will be, according to the project, 10 m/sec [1,970 ft/min]. With the landing gear extended the sink rate can be expected to be about 18 m/sec [3,540 ft/min]. Bearing in mind that, the lower the lift/drag ratio is, the greater should the relative speed reserve be during the gliding descent, the sink rate during a gear-down landing should be calculated at a speed ensuring a flat flare-out.

7. The advanced development project envisages the possibility of using the ailerons as trim tabs. If the ailerons, when used as trim tabs, are slightly raised, this will worsen the effective wing aspect ratio; this should be taken into account when calculating the aircraft's landing performance.

8. Worthy of note is the statement made by designer Comrade Bereznyak (p.18) that it is possible, without serious modifications of the aircraft, to increase the range of powered flight to 600 km [373 miles] and the endurance in powered flight to 1 hour while retaining the other performance characteristics listed in the ADP. This may provide a solution to the problem of returning to base and ensure acceptable landing performance.

9. The aircraft's take-off has been studied in the project for two options: a take-off by means of a take-off dolly (sled) with solid-fuel boosters, and a take-off using a jettisonable undercarriage without boosters. The take-off with a jettisonable undercarriage reduces the optimum range of the aircraft by some 5%, but it is simpler in operation and also ensures acceptable take-off performance.

10. The airbrakes envisaged on the aircraft reduce the maximum speed of level flight at 15,000 m [49,200 ft] by 40% in the course of 33 seconds and enable the aircraft to dive vertically from an altitude of 24,000m [78,720 ft]. However, their effectiveness has been determined only by calculations and requires checking by means of wind tunnel tests.

11. The landing speed of 182 km/h [113 mph] specified in the project can be obtained only in the case of landings performed with an angle of attack up to 24°.

12. The multi-chamber rocket motor, the installation of which is envisaged by the ADP, has quite realistic design performance and meets modern requirements. This motor has in part been developed, built and tested by OKB-2 of MAP plant No.1.

13. The use in the motor of the *Kenaf* (Ambary) concentrate which is added to kerosene before injection of the latter into the combustion chamber calls for additional experimental work connected with determining the properties of this admixture. The final development of techniques of using *Kenaf* may require a more exact definition of the general layout of all powerplants.

[...]

Design Performance of the '470' Interceptor as per ADP Documents

Maximum speed at altitudes in excess of 11,500 m (37,720 ft), km/h (mph)	1,910 (1,187)
Landing speed, km/h (mph)	182 (113)
Time to altitude, minutes:	
to 20,000 m (65,600 ft)	2.24
to 22,000 m (72,160 ft)	2.33
Range in level flight with the rocket motor ignited, km (miles):	
at an altitude of 22,000 m (72,160 ft) and a speed of Mach 1.5	213.6 (133)
at an altitude of 13,000 m (42,640 ft) and a speed of Mach 0.8	264 (164)
Range at an altitude of 22,000 m, taking into account the distance covered during climb and gliding descent, km (miles)	502 (312)
Endurance in level flight with the rocket motor ignited, minutes:	
at 15,000 m (49,200 ft) at Mach 0.8	18.25
at 22,000 m (72,160 ft) at Mach 1.5	8.09
Endurance with the rocket motor ignited, minutes:	
at 22,000 m and Mach 1.5, taking into account the time for take-off, acceleration and climb	10.42
at 22,000 m, taking into account the time for take-off, acceleration, climb and gliding descent (the latter after the shutdown of the motor)	35.56
Take-off run, m (ft)	
from a dolly (sled) with rocket boosters	171 (560)
with a jettisonable wheel undercarriage/no rocket boosters	680 (2,230)
Landing run with airbrakes deployed, m (ft)	610 (2,000)

15. It is necessary to preclude the possibility of a fire in the event of the tanks holding the *Kenaf* concentrate being hit by a cannon shell.

16. The project makes no provision for a device which ensures normal fuel feed in a flight with negative G forces during the aircraft's gliding descent.

17. The project envisages the use of solid-fuel boosters for take off. These boosters are very costly because the nitroglycerin gunpowder used in them is in short supply and because they are not reusable. In addition, the thrust and burn time of these boosters depend to a considerable extent on the ambient temperature. Therefore it is more expedient to foresee the use of liquid-propellant rocket boosters for this purpose. Liquid-propellant boosters are also superior to solid-fuel booster as regards the specific weight.

[...]

23. The dimensions of the cockpit have not been specified in the project and cannot be assessed.

[...]

25. The ADP contains calculations determining the limitations for safe ejection of the pilot. The results of these calculations [...] show that at altitudes below 17,000 m [55,760 ft] the ejection seat does not guarantee the pilot's survival within the whole range of speeds afforded by the aircraft's aerodynamics and airframe strength. In this case ejection may be possible only after rocket motor shutdown and deceleration. However, the limits of safe ejection cited in the project are too high. Tests show that the trajectory of an ejection seat with a man in it passes much lower above the fin as compared to the trajectory of a seat with a dummy. Also, the limits of safe ejection determined by the impact of the slipstream on the pilot have been used at too high values in the calculations.

26. The project specifies the KP-15, KP-18 and KP-20 oxygen apparatus which cannot be used with the high-altitude rescue pressure suit.

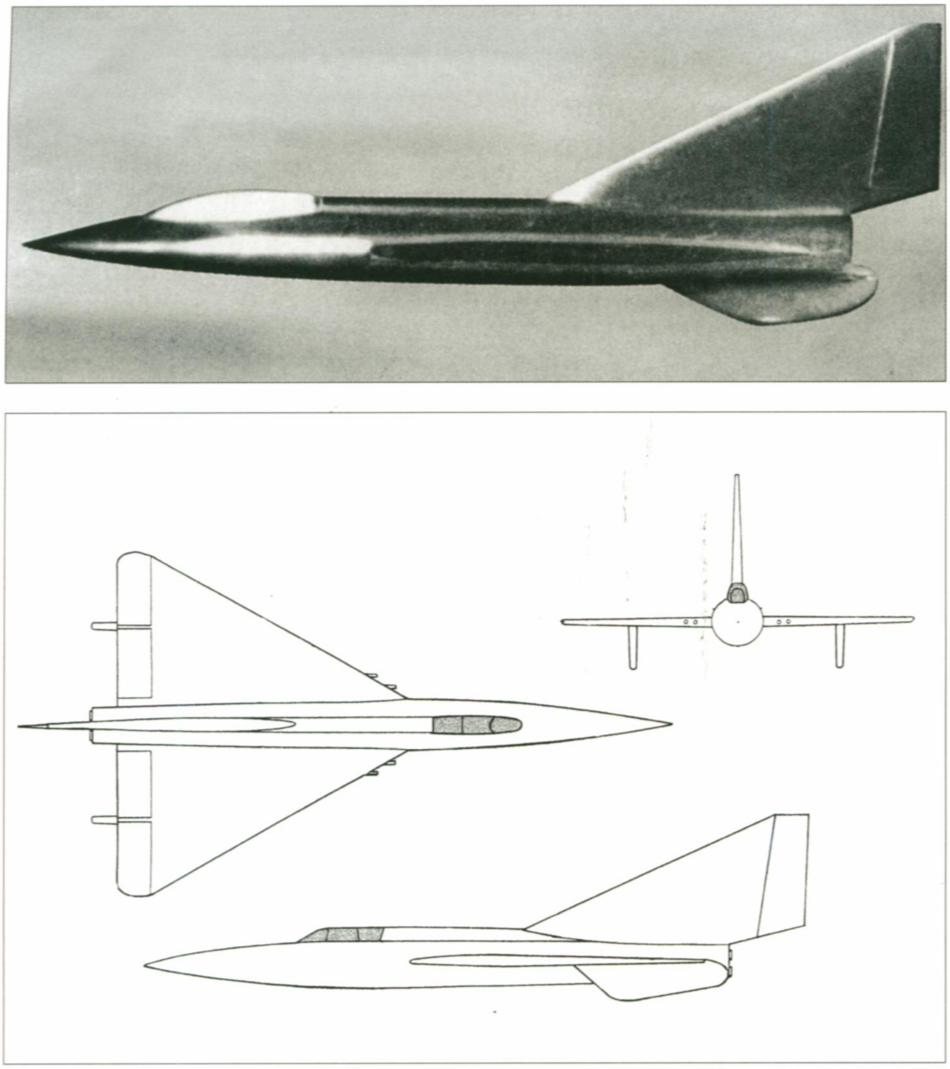
27. For the purpose of airframe strength calculations the design all-up weight is assumed to be 6,500 kg [14,330 lb], which is equal to the aircraft's all-up weight after take-off and climb to 8,000 m [26,240 ft].

The design dynamic pressure limit has been chosen as 5,000 kg/m² [1,024 lb/sq ft], which permits the aircraft to fly at a maximum speed equivalent to Mach 1.8 only at altitudes in excess of 11,400 m [37,400 ft]; this can be considered admissible for this type of aircraft. At an altitude of 8,000 m [26,240 ft] the never-exceed speed shall be Mach 1.4.

28. The control surfaces installed on the wings are subdivided into elevators and ailerons. This distinction in the functions and the provision for eventually using the ailerons as trim tabs is expedient, because this allows the aircraft to be controlled manually in the event the powered control system fails.

29. The control rods to the aircraft's control surfaces are grouped together and accommodated in a fairing in the upper side of the fuselage; this is not expedient from the point of view of the aircraft's survivability because in this case a single shell can disable all controls of the aircraft.

30. In the event one of the hydraulic accumulators or one of the oil tanks or one of the



Another model (left) and a three-view drawing of the '468' or the very similar '470' interceptor.

control boosters fails, the entire powered control system is disabled, which is unacceptable from a survivability standpoint.

31. The ADP envisages a sideways-hinged cockpit canopy, which is inexpedient from a flight safety standpoint in the event of the canopy opening spontaneously in flight.

32. In accordance with the advanced development project the interceptor's armament has been projected in three versions:

- four 23-mm Sh-3 cannons with an ammunition complement of 90 rpg;
- two automatic three-tube launchers with six TRS-132 rocket projectiles;
- four FAB-50M9 bombs for precision bombing.

On the first prototype of the fighter it is expedient to install cannon armament comprising:

- two 30-mm cannons with an ammunition complement of 50 rpg;
- two 23-mm cannons using VYa ammunition (that is, suitable for the Volkov/Yartsev VYa cannon – *Auth.*) with 70 rpg.

According to a statement made by designer Bereznyak, it is possible to install this armament on the aircraft.

[...]

34. Simultaneously with the installation of cannon armament on the aircraft the following armament options should be studied on the drawing board:

- six TRS-190 spin-stabilised rocket projectiles;
- two 100-kg [220-lb] anti-aircraft bombs or two OFAB-100M bombs.

[...]

42. [...] It is expedient to install the RSIU-3M radio with two receivers.'

The same document contained the following conclusions:

'1 The advanced development project of an interceptor with a multi-chamber liquid-fuel rocket motor developed by designer A. Ya. Bereznyak (manufacturer's designation '470') contains sufficiently comprehensive calculations substantiating the design performance.

The design performance specified in the project basically meets the Air Force requirement posed for this type of interceptors.

2. The aerodynamic calculations have been made proceeding from the results of the '466' and '468' models' wind tunnel tests and from theoretical studies; wide use has been made of technical literature published abroad. Therefore it is necessary to adjust the calculations proceeding from the results of wind tunnel testing of the '470' aircraft model, conducted at TsAGI. The static stability and controllability characteristics shall be refined by wind tunnel tests of the aircraft's model. It is also necessary to determine by means of calculations the aircraft's dynamic characteristics and pay special attention to ensuring acceptable characteristics of the gliding descent prior to a landing and of the landing itself.

3. The design characteristics of the multi-chamber liquid-fuel rocket motor intended for the aircraft meet modern requirements posed for engines of this type. It is expedient to continue the development of this motor, which is conducted by OKB-2 of MAP plant No.1.

4. In accordance with the aircraft's mission it is expedient to fit it with cannon armament comprising two 30-mm cannons and two 23-mm cannons using 'VYa' ammunition. At the same time drawings should be prepared of two armament options: the installation of six TRS-190 spin-stabilised rocket projectiles and the installation of antiaircraft bombs.

5. During the final improvement of the aircraft's ADP the designers shall take into account the remarks on deficiencies made in the conclusion on the ADP.'

Next came the Conclusion itself.

'1. The advanced development project of an interceptor with a multi-chamber liquid-fuel rocket motor developed by designer A. Ya. Bereznyak has been prepared in sufficient detail. Owing to its design characteristics this aircraft is of interest for the Air Force.

2. It is considered expedient to task designer Bereznyak with developing a rocket-powered interceptor with due account of the remarks stated in the conclusion on the aircraft's ADP.'

However, as early as the middle of 1951 it became obvious that the use of liquid-fuel rocket motors on combat aircraft was inexpedient because of the all-too-short endurance. In June 1951 MAP stopped funding new projects of OKB-2. Shortly thereafter the design bureau was closed down and its personnel was transferred to other departments of the Plant.

Lastly, the author would like to draw the reader's attention to an interesting fact. In the 'Advanced development project of the '470' interceptor' and in the 'Conclusion on the Advanced development project of the '470' interceptor' A. Ya. Bereznyak is named as the aircraft's designer. There is no mention at all of German designers.

Chapter 7

The Quest for Speed

Ts-1 Experimental Aircraft (LL-1, LL-2 and LL-3 Flying Testbeds)

In the second half of 1945 a team headed by Pavel Vladimirovich Tsybin started developing a special aerial vehicle intended for conducting research and practical experiments in the air. These experiments were meant to solve the problem of selecting the most advantageous wing shape for aircraft flying at high subsonic and transonic speeds. The projecting and construction of the machine proceeded with due regard to the programme of future experiments and research which had been developed by TsAGI scientists jointly with prominent specialists of the aircraft industry. In early 1947 the aircraft, which was designated Ts-1, was submitted for testing. It was, in effect a flying testbed, or 'flying laboratory' in Soviet parlance, hence its other designation – LL-1 (LL = *letayushchaya laboratoriya* – flying laboratory)

The Ts-1 had an all-wooden construction with a plywood skin. It had unswept flat wings with an area of 10.2 m² (109.8 sq ft), with two spars made of ***del'ta-drevesina*** ('delta wood') – a moulded composite of wood impregnated with phenol formaldehyde resin. The tail unit had a cruciform layout, the horizontal tail being set half-way up the fin; the rudder and elevators featured mass balances. Prior to a flight in glider mode, special ballast tanks in the aircraft's fuselage were filled with up to 1,000 kg (2,200 lb) of water.

The Ts-1 was powered by a solid-fuel rocket motor. In its size, weight and, primarily, because of its high thrust yield and high acceleration ability, it was best suited for the short-duration design flights modes of the research and experimental flights. Besides, in 1945 there were no well-developed turbojets that were suitable in terms of their weight and thrust.

Instead of a conventional undercarriage the Ts-1 featured a twin-wheel axle-dolly (that is, the dolly was no more than an axle linking the two wheels) and a landing skid mounted on the aircraft's centreline. The Ts-1 performed its take-off and a climb to altitude on tow behind a Tu-2. The dolly was jettisoned immediately after lift-off. At an altitude of 5 to 7 km (16,400-22,960 ft) the aircraft cast off and the test pilot put the Ts-1 into a dive, the diving angle being between 45° and 60°. At a straight-line section of the diving trajectory the pilot ignited the rocket motor. In this mode the Ts-1 attained a speed of 1,000-1,050 km/h (621-653 mph).

The PRD-1500 solid-fuel rocket motor (*porokho**voy** ra**ket**nyy **dvig**atel'* – 'gunpowder rocket motor') developed by the design team of engineer I. I. Kartukov yielded a thrust of up to 1,500 kgp (3,310 lbst). It was installed in the rear fuselage of the aircraft beneath the tail unit. Its running time was 8 to 10 seconds. This ensured level flight with a speed of up to 900 km/h (559 mph).

During the few seconds of the steep dive the onboard equipment registered the airflow parameters, photos were taken of the airflow pattern (to this end the wings were covered with wool tufts), and other tasks envisaged by the test mission were accomplished. Then the 1-tonne water ballast that was no longer needed was drained into the atmosphere. The Ts-1, having thus lost half of its weight, performed flight manoeuvres like a normal glider and touched down on the underfuselage skid. At a take-off weight of 2,039 kg (4,495 lb), the Ts-1's lift-off speed was 150-160 km/h (93-99 mph); with the water jettisoned and the weight reduced to some 1,100 kg (2,425 lb), the landing speed did not exceed 120 km/h (75 mph).

The testing of the Ts-1 was conducted by test pilot M. Ivanov. Subsequently Amet-Khan Sultan, S. N. Anokhin, N. S. Rybko and other test pilots flew the experimental machine. Nearly 30 flights were performed on the Ts-1 in its straight-wing configuration (LL-1). That was the first stage of the experiments. Further experiments in the programme presupposed alterations in the aircraft's lifting surfaces.

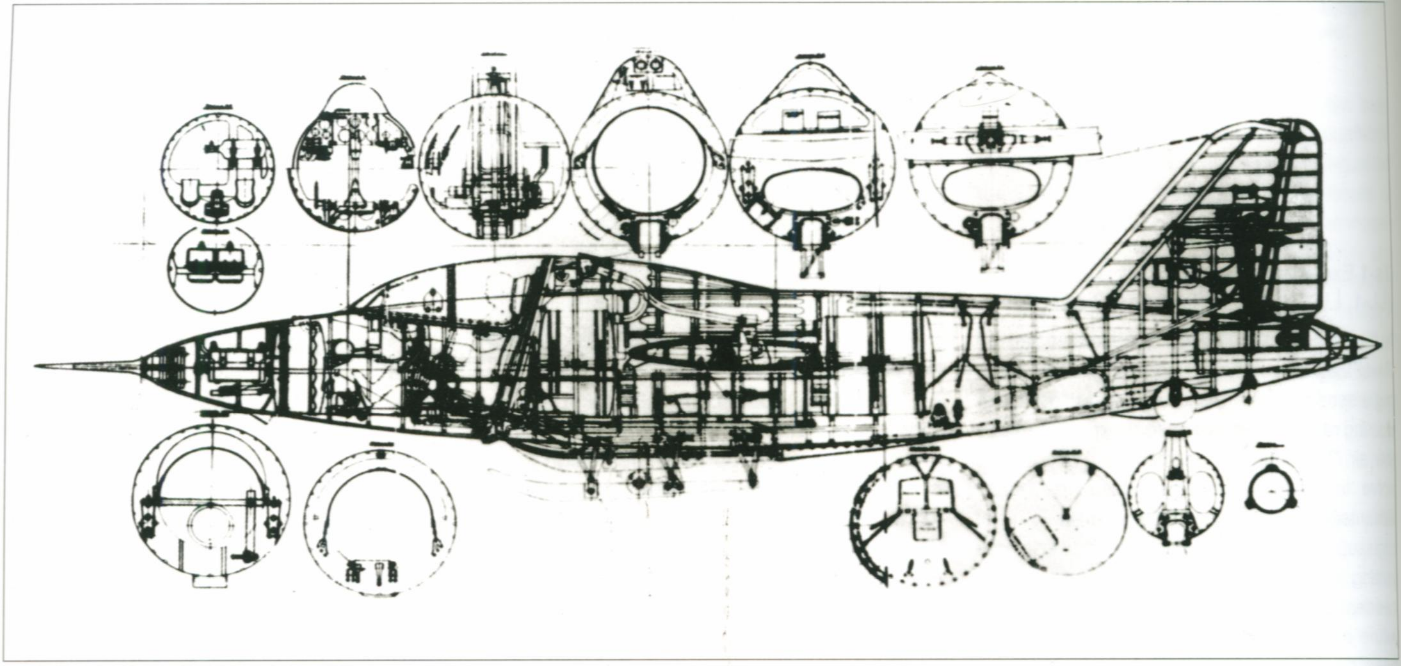
As early as 1946, a design group led by A. V. Beresnev projected two sets of metal (duralumin) wings to be mated with the second Ts-1 fuselage/vertical tail assembly. The new wings had the same area and aspect ratio as the original wooden wings. One set was swept-back, while the wings of the other set were swept forward, with the same leading-edge sweep angle (+30° and –30° respectively). The horizontal tail was also designed anew; it was swept-back, with 40° leading-edge sweep. The Ts-1 version with swept-back wings having 4° anhedral was designated LL-2, while the version with forward-swept wings and 12° dihedral was known as the LL-3.

The wing panels of the new wing sets had standardised attachment points – that is, they were attached to the fuselage by the same fittings as the wooden straight wings of the LL-1. Therefore the changes in the CG position associated with the new position of the MAC and aerodynamic centre after the installation of new wings were compensated by adjusting the amount of water ballast in the forward and rear fuselage tanks. Calculations of the optimum filling of the tanks were made, providing an acceptable stability margin for both wing versions.

The forward-swept wings were installed on the second Ts-1 airframe. During the flights of the LL-3, which numbered nearly a hundred, somewhat greater diving speeds were attained as compared to the straight-wing LL-1; the aircraft reached 1,150-1,200 km/h (715-746 mph) or Mach 0.95-0.97. As a result, the researchers succeeded in studying the properties of the little-known forward-swept wings and the properties of an FSW aircraft in general.

The LL-2, on the other hand, never flew; there was no point in testing it because two turbojet-powered fighters featuring wings with 35° sweepback at quarter-chord – the Mikoyan/Gurevich I-310 (MiG-15) and the Lavochkin La-15 – had undergone comprehensive testing in 1948. Furthermore, the wooden structure of the first Ts-1 fuselage already showed signs of wear and could no longer guarantee flight safety; as for the second Ts-1 example, it was decided not to fit the sweptback wings to it. To obtain as much data as possible, a multitude of strain gauges and dynamographs were placed in the fuselage and wings of the Ts-1. Photo cameras were mounted near the wing roots; in flight they registered the oscillations of the wool tufts caused by local turbulence of the airflow, as well as the position of shock waves at different moments of the aircraft's acceleration.

The flights of the Ts-1 in the LL-1 and LL-3 versions and the research conducted on them provided scientists with unique materials on the aerodynamic characteristics of aircraft fitted with different types of wings, on the spanwise and chordwise distribution of the airflow pressure, on the emergence and travel of shock waves (compression shocks) and flow separation areas behind them at critical



Above: A cutaway drawing of the Ts-1 research aircraft. In this case, no rocket motor appears to be fitted.

	LL-1	LL-2	LL-3
	(unswept wings)	(swept-back wings)	(forward-swept wings)
Length, tail up (less pitot)	8.98 m (29 ft 5½ in)	8.98 m (29 ft 5½ in)	8.98 m (29 ft 5½ in)
Wing span	7.1 m (23 ft 3½ in)	7.1 m (23 ft 3½ in)	7.22 m (23 ft 8¼ in)
Horizontal tail span	2.55 m (8 ft 4$\frac{13}{32}$ in)	2.55 m (8 ft 4$\frac{13}{32}$ in)	2.55 m (8 ft 4$\frac{13}{32}$ in)
Landing gear wheelbase	3.95 m (13 ft 0 in)	3.95 m (13 ft 0 in)	3.95 m (13 ft 0 in)
Leading-edge sweep	n.a.	+30°	–30°

Mach numbers, on the relationship between the increase of the control surfaces' hinge moments and of the flight speed, on the special features and changes of parameters of the boundary layer, and other things.

Apart from studying the properties of transonic flight modes, interchangeable sets of wings of the Ts-1 ensured also a uniquely clean experiment providing comparison between different configurations of the lifting surface. There was every reason to think that differences in the behaviour of the aircraft were caused by the interchangeable wings.

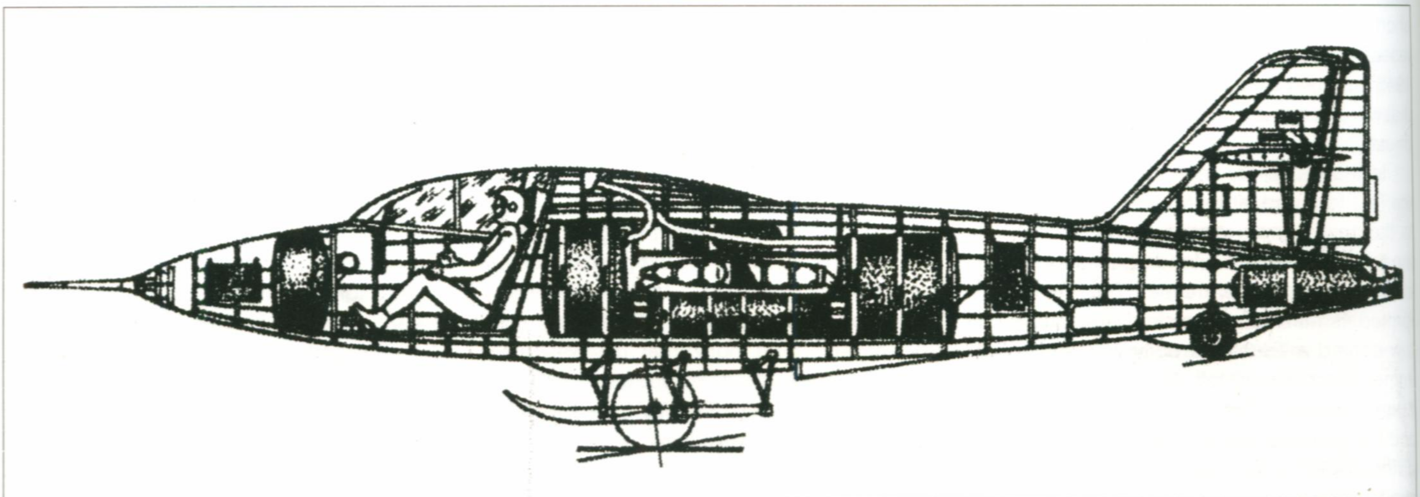
In the course of the testing of the Ts-1, in August 1947, Lt. Col. Sergey N. Anokhin was awarded the qualification of Test Pilot 1st Class. In 1949 he was promoted to Colonel.

The table on this page gives some dimensions of the Ts-1 airframe's three versions.

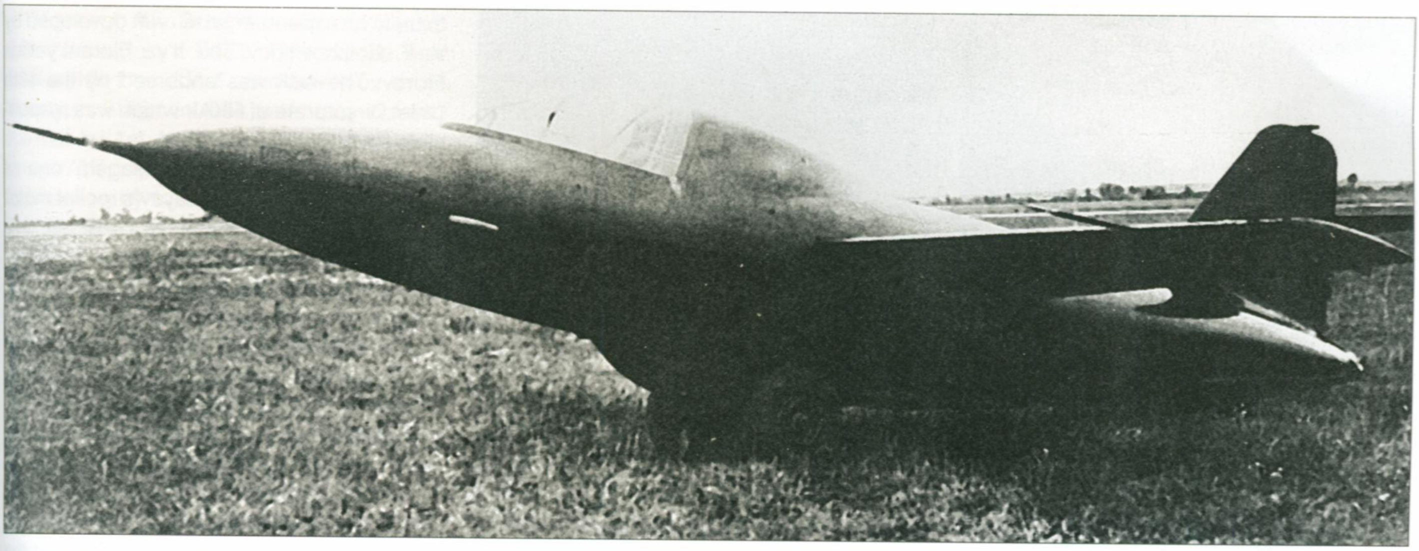
'4302' Experimental Aircraft

On 18th February 1944 the State Defence Committee issued directive No.5201 which tasked the Rocket Technology Institute (NII-1, the former GIRT where Andrey G. Kostikov had formerly been chief engineer), now subordinated to the People's Commissariat of Aircraft Industry, with the development of jet engines. P. I. Fyodorov, former chief of NII VVS, was appointed chief of NII-1; his deputy was Viktor F. Bolkhovitinov at whose design bureau the BI, the first Soviet rocket-propelled interceptor, had been developed.

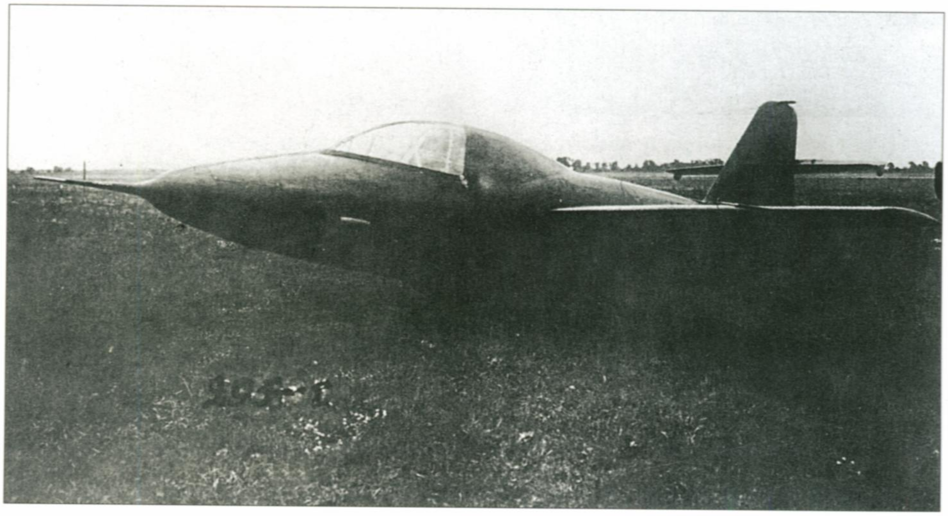
The new leaders of NII-1 had a predilection for aircraft construction. Therefore, in addition to the main bulk of work on liquid-fuel rocket motors conducted by the teams of Aleksey M. Isayev and Leonid S. Dooshkin, and the work on turbojets for which Arkhip M. Lyul'ka's team was responsible, they decided



Another cutaway drawing of the Ts-1, showing the solid-fuel rocket motor.

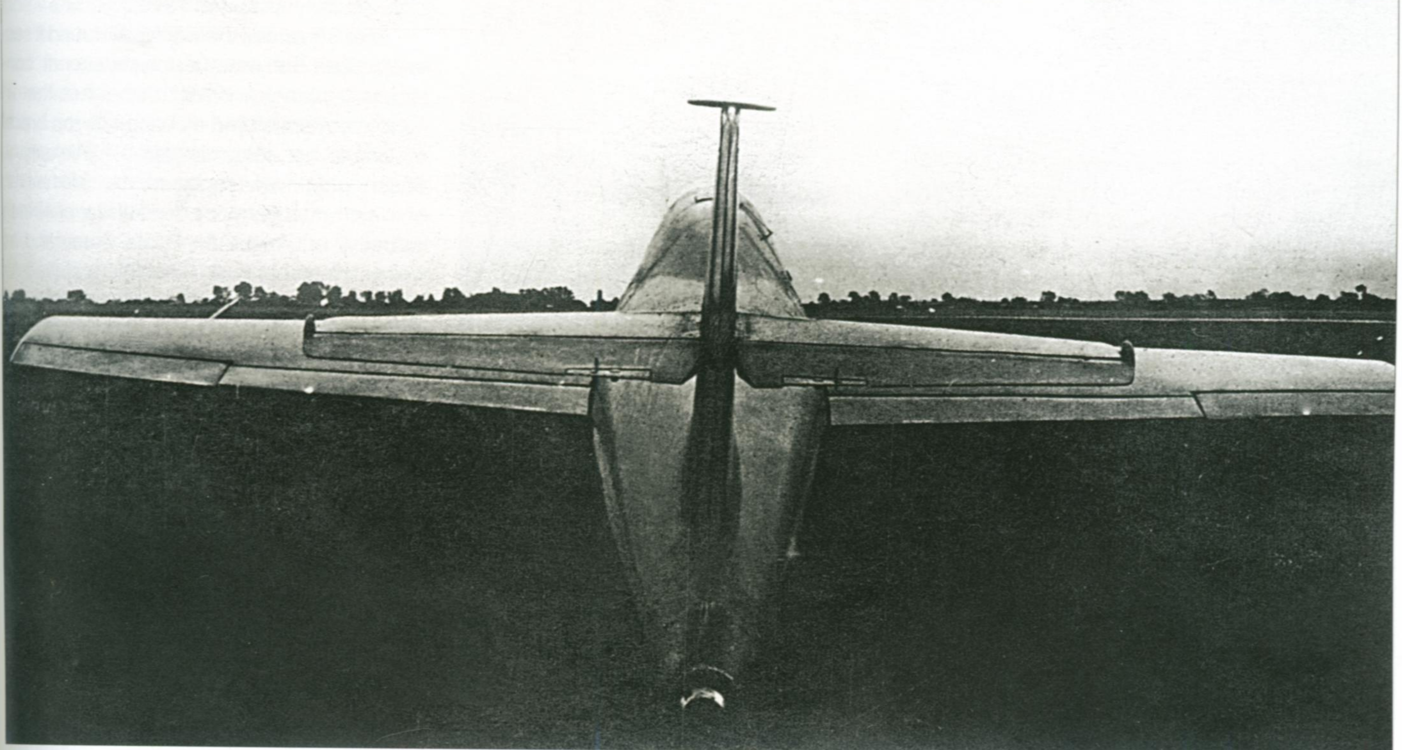


Above: The Ts-1 in its original straight-wing form known as the LL-1 with the take-off dolly attached. The size of the cockpit gives an idea how small the aircraft really was. With the dolly in place, the Ts-1 had a very strong nose-up attitude.



Right: The same aircraft sitting on its landing skid.

Below: Rear view of the LL-1, showing the cruciform tail unit. The stabilisers are likewise unswept.

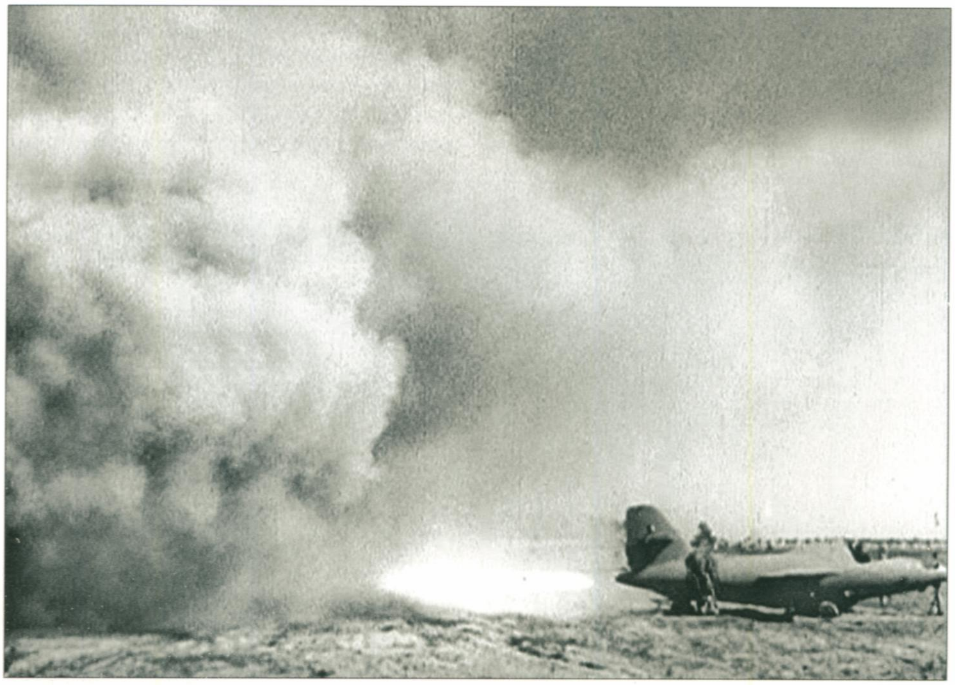


Above: Test pilot Lt. Col. Sergey N. Anokhin who test flew the Ts-1 experimental aircraft in its LL-1 and LL-3 versions.

Above: Test pilot Amet-Khan Sultan, twice Hero of the Soviet Union, also participated in the tests of the Ts-1.

Comparative Specifications of the '4302' and '4303' Development Aircraft

Type	'4302'	'4303'
All-up weight, kg (lb)	2,320 (5,114)	2,350 (5,180)
Maximum sped, km/h (mph):		
at sea level	1,010 (627)/Mach 0.82)	1,040 (645)/Mach 0.85)
at 5,000 m (16,400 ft)	1,015 (630)/Mach 0.88)	1,050 (652)/Mach 0.91)
at 15,000 m (49,200 ft)	1,050 (652)/Mach 0.99)	1,090 (677)/Mach 1.03)
Climb time to 15,000 m	2 min 22 sec	1 min 42.4 sec
Service ceiling, m (ft)	18,850 (61,850)	19,750 (64,800)
Endurance, minutes	Up to 46	Up to 46



The LL-1 creates a local dust storm as a test firing of the rocket motor is performed.

to build an experimental aircraft developed by V. F. Bolkhovitinov and Il'ya Florent'yevich Florov. The task was endorsed by the 18th Chief Directorate of NKAP which was responsible for the jet hardware.

Two versions were envisaged, one of them to be powered by Isayev's rocket motor (aircraft '4302'), and the other by Dooshkin's rocket motor (aircraft '4303'). The basic design performance figures of these aircraft are given in the table on this page.

Both aircraft were intended for research on liquid-fuel rocket motors and on the aerodynamics of high-speed flight, as well as for formulating the law of chordwise pressure distribution and of the loads arising during flight in the region of shock stall. In all, six examples were to be built, of which the first two were intended for pilot training and the rest for the experimental work. The capacity of the institute's own production facility was insufficient; therefore, the airframes were built by plant No.21 - a major aircraft factory in Gor'kiy (at present the 'Sokol' (Falcon) plant in what is now called Nizhniy Novgorod). There the rocket-powered aircraft received the in-house designation 'type 47'. By 1st January 1946 the manufacturing drawings had been completed and transferred to the workshops. Three examples of 'type 47' were under construction at the plant almost concurrently; they differed in airframe structure, landing gear design and powerplant but shared the same basic layout with shoulder-mounted unswept wings and conventional tail surfaces featuring endplate fins. The first two machines were to be rolled out from the assembly workshop as early as March 1946.

After the end of the war NKAP found it easier to draft the new prototype aircraft construction plan by virtue of the fact that in February-March 1946 a change of 'top brass' occurred not only in NKAP (Aleksey I. Shakhoorin was replaced by Mikhail V. Khrunichev as People's Commissar of Aircraft Industry) but in the Air Force Command as well (Air Marshal K. A. Vershinin replaced Air Marshal Aleksandr A. Novikov as Commander-in-Chief of the Air Force). While the reshuffle at the command posts went on, the military had other business to attend to than the prototype aircraft construction plan. It would seem that the situation was taking a favourable turn for NKAP (renamed MAP, the Ministry of Aircraft Industry, in March), and several new projects could be included into the plan. However, the new leaders of the aircraft industry did not fancy the idea of building an experimental aircraft developed by NII-1 – they held the opinion that the institute had engaged in work which was outside its direct sphere of competence. Therefore in February 1946 the funding of this programme was halted.

However, the designers did not put up with this decision. Ya. L. Bibikov, the new chief of NII-1, and V. F. Bolkhovitinov wrote directly to Stalin; in their letter they pointed out that by 1st April the first prototype was almost 70% complete and would be ready for flight testing by 1st July in the event the work was allowed to continue. Vice-Chairman of the Soviet Council of Ministers N. A. Voznesenskiy, who had overall responsibility for aviation matters, instructed Khrunichev and Vershinin to look into the matter and submit their proposals.

The new Air Force C-in-C Vershinin had a 'soft spot' for the construction of advanced aircraft; besides, he was somewhat hurt by the fact that the plan for prototype aircraft construction had been approved without consultation with the Air Force. Therefore, together with the new Chief Engineer of the Air Force, Colonel-General of Aeronautical Engineering Service I. V. Markov, he expressed his support for the designers. In their reply they wrote:

'The experimental aircraft designed by Florov, which is being built in an interceptor version at MAP's NII-1, is undoubtedly of interest because its design performance includes speed and rate of climb considerably superior to those of the fighter-type combat aircraft series-produced at present.

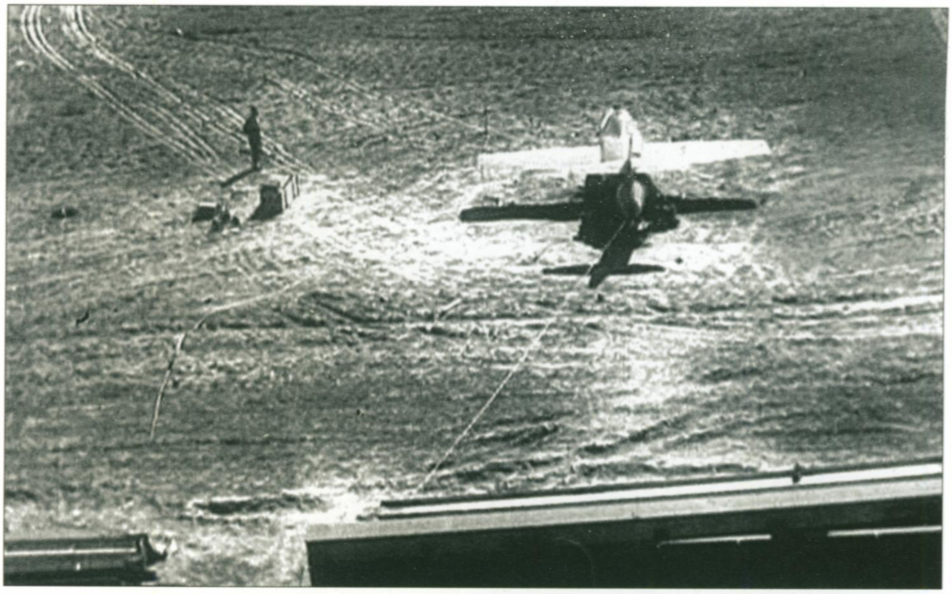
Construction and testing of this aircraft will contribute to the development of measures aimed at further increasing the speeds of combat aircraft. I consider it necessary to give NII-1 an opportunity to complete the construction of the experimental aircraft designed by Florov and to conduct its flight testing in 1946.'

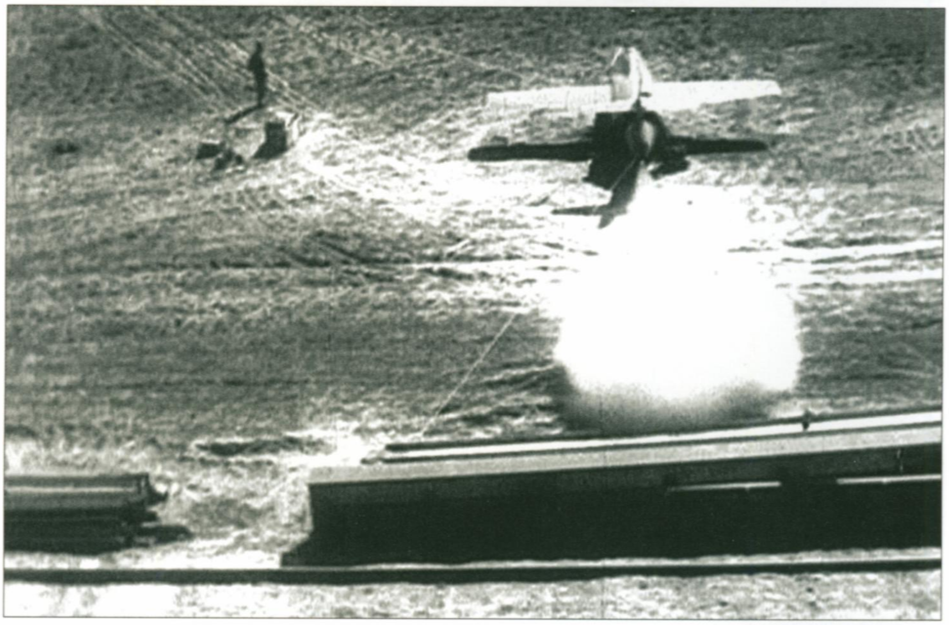
Khrunichev's reaction was as follows:

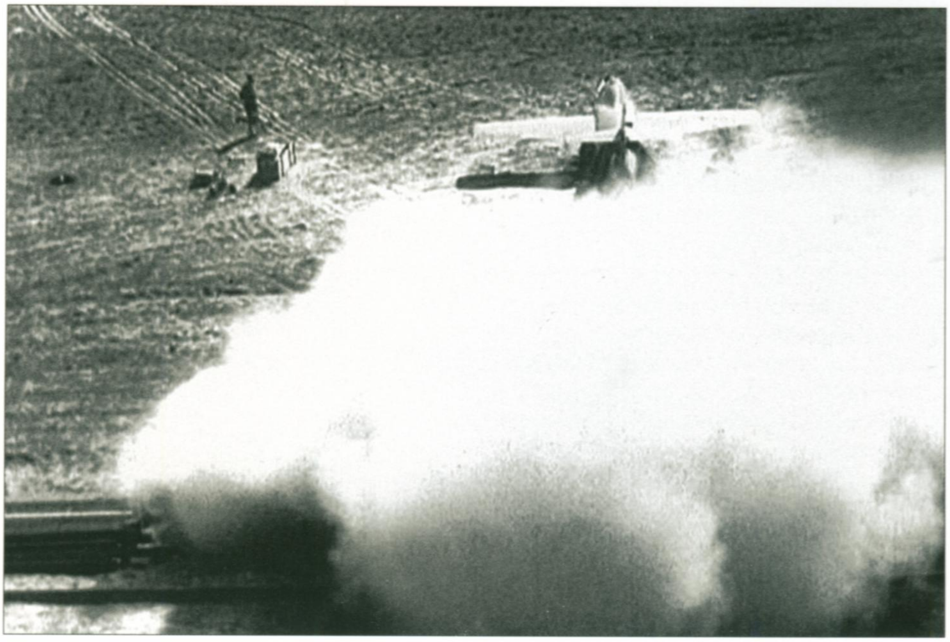
'...I report that the submitted design performance figures of the experimental aircraft with a liquid-fuel rocket motor, under development at NII-1, cause doubts. A highly competent commission comprising specialists of the Ministry has been set up to verify the realistic character of these figures...'

The commission headed by Professor I. V. Ostoslavskiy comprised Chief Designer of OKB-155 A. I. Mikoyan, section chief at TsAGI V. N. Matveyev, group chief of MAP's 7th Chief Directorate I. V. Loktev and section chief of MAP's 8th Chief Directorate V. V. Yakovlevskiy. By early June 1946 the commission submitted the following conclusion on the project:

'...the aircraft's maximum speed will be 900-950 km/h [559-590 mph] instead of 1,000-1,100 km/h [621-683 mph], and the aircraft's service ceiling will be limited to 12,000-







The three photos on this page also show the LL-1 going through a ground run of the rocket motor. A second after the motor is ignited, the jet blast deflector behind the aircraft disappears in a pall of powder smoke and dust.

Top, centre and above: The LL-1 takes off on a towed flight; the towing line attachment is in line with the canopy's front end.

The Ts-1 in flight in its LL-1 configuration.

13,000 m [39,360-42,640 ft] instead of 20,000 m [65,620 ft] due to the absence of cockpit pressurisation on the aircraft. The aircraft's endurance stated in the letter is 46 minutes; the commission has ascertained that the maximum flight endurance will be about 5 minutes.'

The members of the commission proceeded, in particular, from the assumption that the aerodynamic layout of the straight-wing aircraft developed as early as 1944 did not permit it to attain the advertised speeds. However, Il'ya F. Florov insisted that the aircraft was designed in full conformity with the latest strength requirements and made use of high-speed wing airfoils recommended by TsAGI at that time. The designer argued that no new recommendation had been received.

Indeed, the accusations levelled by the MAP commission against NII-1 as regards the alleged 'backwardness' of the project were clearly prejudiced. At that time various captured materials on German research of high-speed aircraft layouts (including layouts with swept-back and forward-swept wings) were available; in addition, TsAGI was obliged to conduct its own comprehensive research prior to giving recommendations. The main problem was that TsAGI had only one high-speed wind tunnel, the T-106, with a working area of 2.6 m (8 ft 6¼ in) diameter and an airflow speed of up to 900-950 km/h (559-590 mph), and the construction of new wind tunnels proceeded at an extremely slow pace.

Despite the commission's findings, MAP received instructions to complete the prototype of the '4302' aircraft and test it.

The fact that the leaders of NII-1 and the designers of the aircraft had been complaining did not fail to produce repercussions on the part of MAP. In September 1946, speaking at a meeting of the ministry's top management body, Minister Mikhail V. Khrunichev demanded that the institute reorganise its activities in the direction of scientific, rather than practical work; he also ordered that the design teams working within the framework of the institute be transformed into independent bodies with their own prototype production facilities. Furthermore, the top figures in the institute's management were replaced. Mstislav V. Keldysh was appointed new chief of NII-1, and the institute came to comprise only three teams: OKB-1 led by Leonid S. Dooshkin, OKB-2 led by Aleksey M. Isayev and OKB-3 led by Mikhail M. Bondaryuk, plus a section dealing with solid-propellant boosters. In compliance with the Minister's order the design bureau headed by Il'ya F. Florov was disbanded and its staff together with its production facilities were placed at the disposal of designer Matus R. Bisnovat. Reorganised in this fashion, NII-1 remained in existence for one more year, whereupon in

1948 it was merged into the Central Aero Engine Institute (TsIAM – *Tsentrahl'nyy institoot aviatsionnovo motoro-stroyeniya*) to which the design bureaux led by Dooshkin and Bondaryuk were transferred. With Isayev's consent, his design bureau was transferred to the system of the Ministry of Armaments where it took on the development of liquid-fuel rocket motors for surface-to-air missiles.

By the autumn of 1946 a flyable airframe of I. F. Florov's aircraft with no rocket motor installed was ready for testing and was moved to LII; meanwhile, the flying prototype with Isayev's rocket motor installed was nearing completion. The military put pressure on MAP and the ministry was forced to continue the preparations for testing the aircraft at LII.

The flights of the '4302' experimental aircraft took place in 1947. A total of 20 flights were performed, of which 19 were conducted in the glider version.

A flyable example of the aircraft which, as mentioned above, conformed to the version with the Isayev-designed single-chamber rocket motor but had no engine installed, was fitted with a non-retractable tailwheel undercarriage. The main gear units were taken from a production La-5FN fighter.

In the first half of 1947 the engineless version of the '4302' was tested in flight on tow behind a North American B-25 bomber piloted by LII test pilot Major M. F. Yakubov, Hero of the Soviet Union. The '4302' made its first flight on 3rd February – on the same day as the first prototype Mikoyan I-270 ('Zh-1') described in the previous chapter. The machine was flown by test pilot Major A. K. Pakhomov. At a take-off weight of 1,350 kg (2,980 lb) the '4302' lifted off at around 170 km/h (106 mph). In these flights the CG position, which was ground-adjustable by means of interchangeable weights, varied within the range of 15% to 24% MAC. During the towed phase of the flight tests, nine flights were performed in February and four more in March; in addition, the aircraft made two high-speed taxi runs with the rocket motor ignited (on 18th February and 8th March).

In June M. F. Yakubov performed three training flights in the '4302'; the machine was towed by a Tu-2 (c/n 2448) with test pilot Igor' I. Shelest at the controls. This is what Yakubov wrote in his flying assessment of the '4302' aircraft (keep in mind that these were flights in glider configuration, after all):

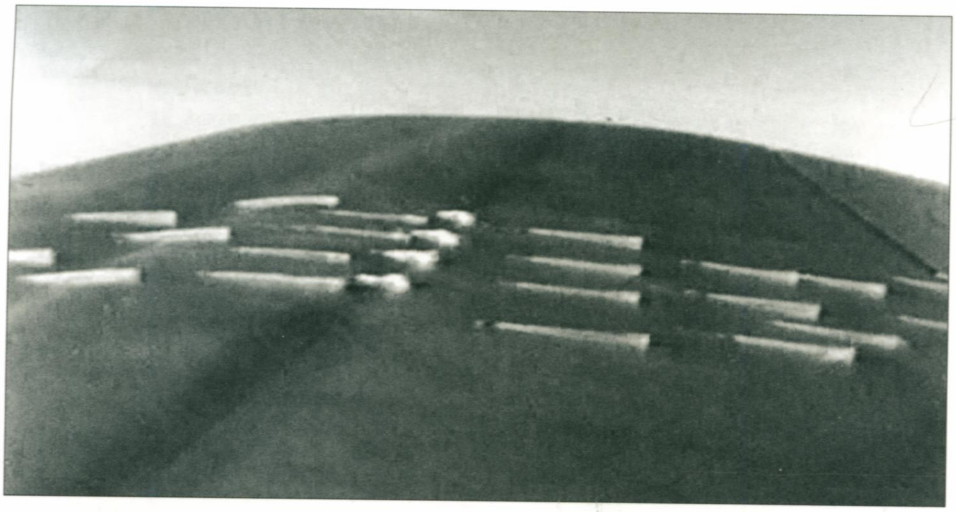
'At an altitude of 5,000 m [16,400 ft] I cast off from the towplane, after which the aircraft made a free gliding flight. The landing was performed on the basis of calculations on a designated spot on the airfield. All three flights proceeded normally. During a take-off on tow behind a Tu-2 the glider is stable, displaying no tendency to yawing.

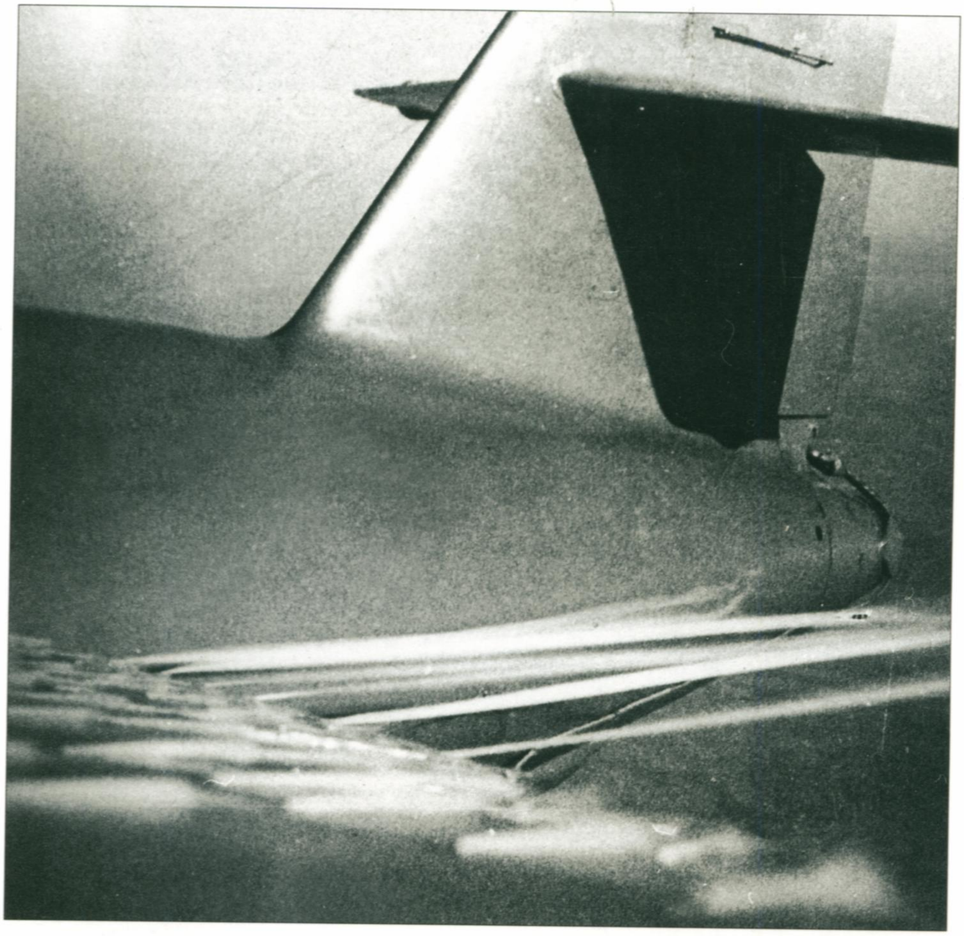
Top and above: Mission accomplished, the LL-1 lands on the same airstrip. Note extended landing skid.

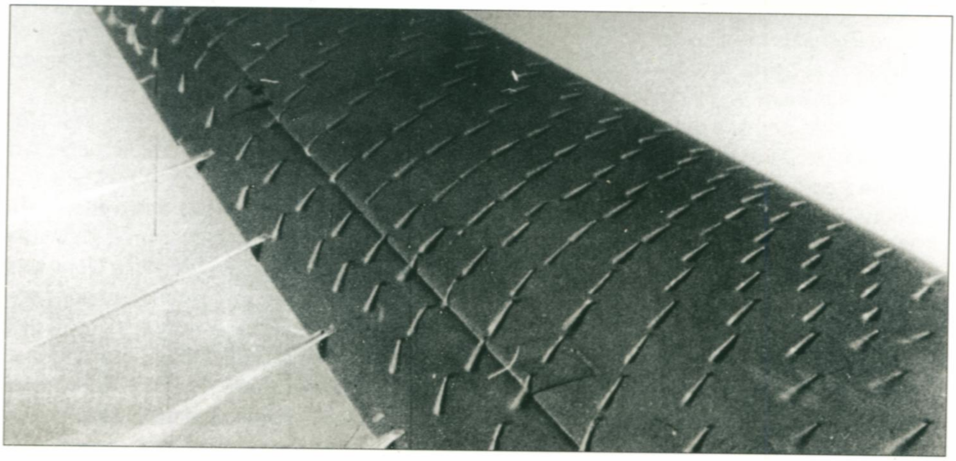
Gliding at speeds of 200-350 km/h [124-217 mph] is stable. The glider has agreeable handling. The stick and pedal forces are not [excessively] high. The glider displays a stable sideslip to both sides. With the flaps lowered the aircraft is stable during gliding and in a side-slip. During the landing the controls are effective and have a sufficient reserve. It is obvious that gliding at high speeds will cause no abnormal effects either. After the flights performed so far I consider myself well prepared for flights at high speeds.'

As mentioned above, the second '4302' airframe was intended to take a rocket motor designed by L. S. Dooshkin and yielding a thrust of 1,100 kgp (2,425 lbst). Instead of the conventional undercarriage, it was fitted with a retractable landing skid and used a three-wheel take-off dolly which was jettisoned almost immediately after the aircraft's lift-off (from a height of 1.5-3 m/5-10 ft). The dolly weighed 150 kg (330 lb) and turned out to be substandard; after being jettisoned it invariably turned over on impact, no matter whether its braking system was activated or not. The need to repair this take-off device caused delays in the testing.

With the onset of warmer days preparations were started for the aircraft to be tested in powered flight. On 31st July A. K. Pakhomov performed two taxi runs and a short hop, and on 1st August 1947 permission was granted for a powered flight. This flight was likewise performed by Pakhomov. After casting off from the towplane he ignited the rocket motor at an altitude of 5,000 m (16,400 ft) and attained a speed of 826 km/h (513 mph). The aircraft's all-up weight with a full load of fuel







and oxidiser was 1,750 kg (3,860 lb). Here's what the pilot wrote in his flying assessment of the aircraft:

'During taxiing and the take-off run the dolly displays stable behaviour and keeps on a straight course, although it is not equipped with a front wheel.

Thanks to its high incidence when placed on the dolly, the glider lifts off at a speed of 150-160 km/h [93-99 mph] after a short run of the towplane; due to this, a large amount of control surface deflection is required to keep the glider in a level flight attitude with the dolly attached…

The dolly was jettisoned from a height of 1.5-3 m [5-10 ft] by pushing a button on the control stick.

Even in a most perfect jettisoning from 1.5-3 m the dolly invariably nosed over both with the brakes automatically activated and with the brakes switched off.

[…]

After the jettisoning of the dolly the glider had no tendency to pitch up; it merely did a slight jerk forward which caused a slackening of the tow cable which […] was rectified by changing the glider's attitude. With the dolly disengaged, the glider became noticeably more stable and its control surfaces became more quick-reacting and sensitive.

With the dolly jettisoned and the skid retracted, controllability and stability are noticeably better, the glider becomes easy to fly and very pleasant in handling.

[…]

When the rocket motor is ignited, the aircraft accelerates quickly and easily attains high speeds; having attained V=826 km/h [513mph] at H=5,000 m [16,400 ft], it behaved well in all respects, there were no vibrations.

The increase of the stick force at this speed was no more than 1.5-2 kg [3.3-4.4 lb], but this did not cause a sensation of the controls becoming stiffer.

[…]

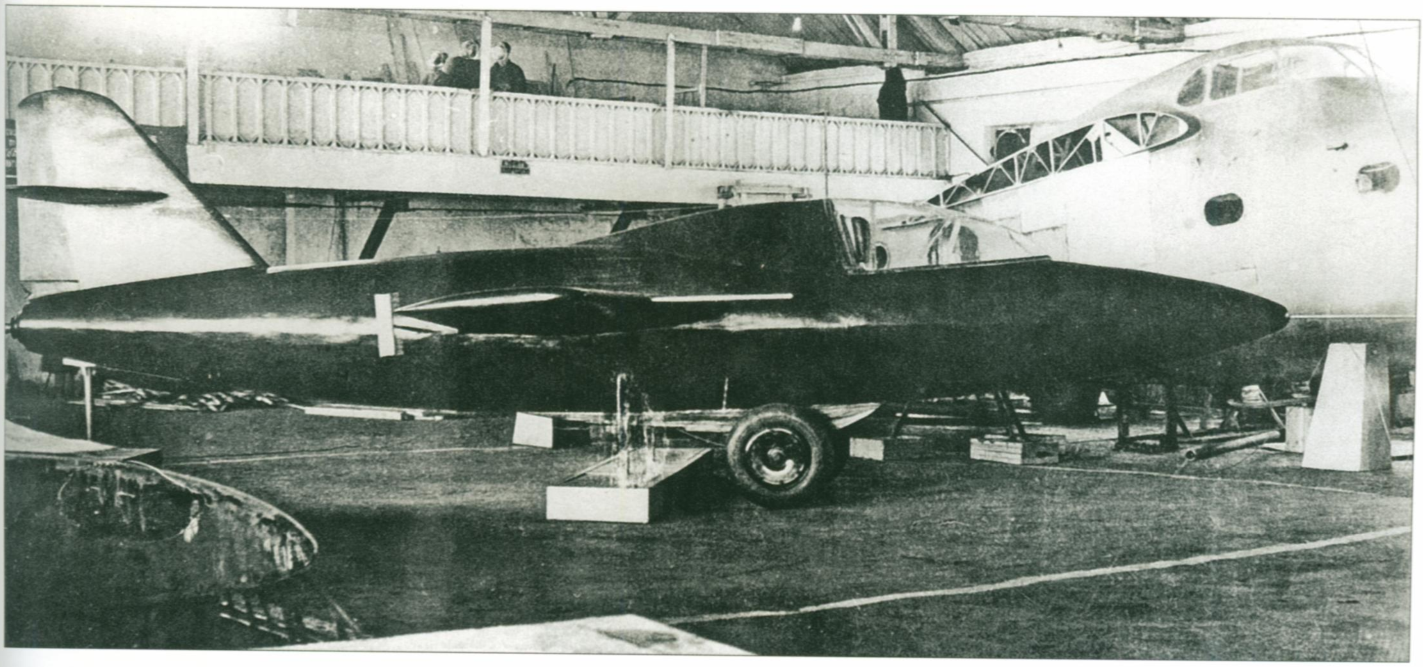
In a headwind the aircraft glides stably at V=160 km/h [99 mph]; it shows stable behaviour during landing and has no tendency to side-slip. The landing is performed at a speed of 125 km/h [77 mph].

[…]

Flights are possible at high speeds around 850-900 km/h [528-559 mph]'.

Top left: The other configuration of the Ts-1 tested in flight was the LL-3 featuring forward-swept wings. This is a close-up of the starboard wing's outer section with airflow visualisation tufts.

Left and above left: In addition to the usual wool tuft, the LL-3's wings had a number of holes along the trailing edge through which smoke was emitted to visualise the airflow aft of the wings. Note how the airflow curves near the trailing edge.



Above: The Ts-1 sits in the Tsybin OKB's experimental shop after conversion to the LL-2 configuration with sweptback wings and stabilisers. This version was not tested in flight. Note the incomplete Ts-25 assault glider (probably the prototype) in the background.

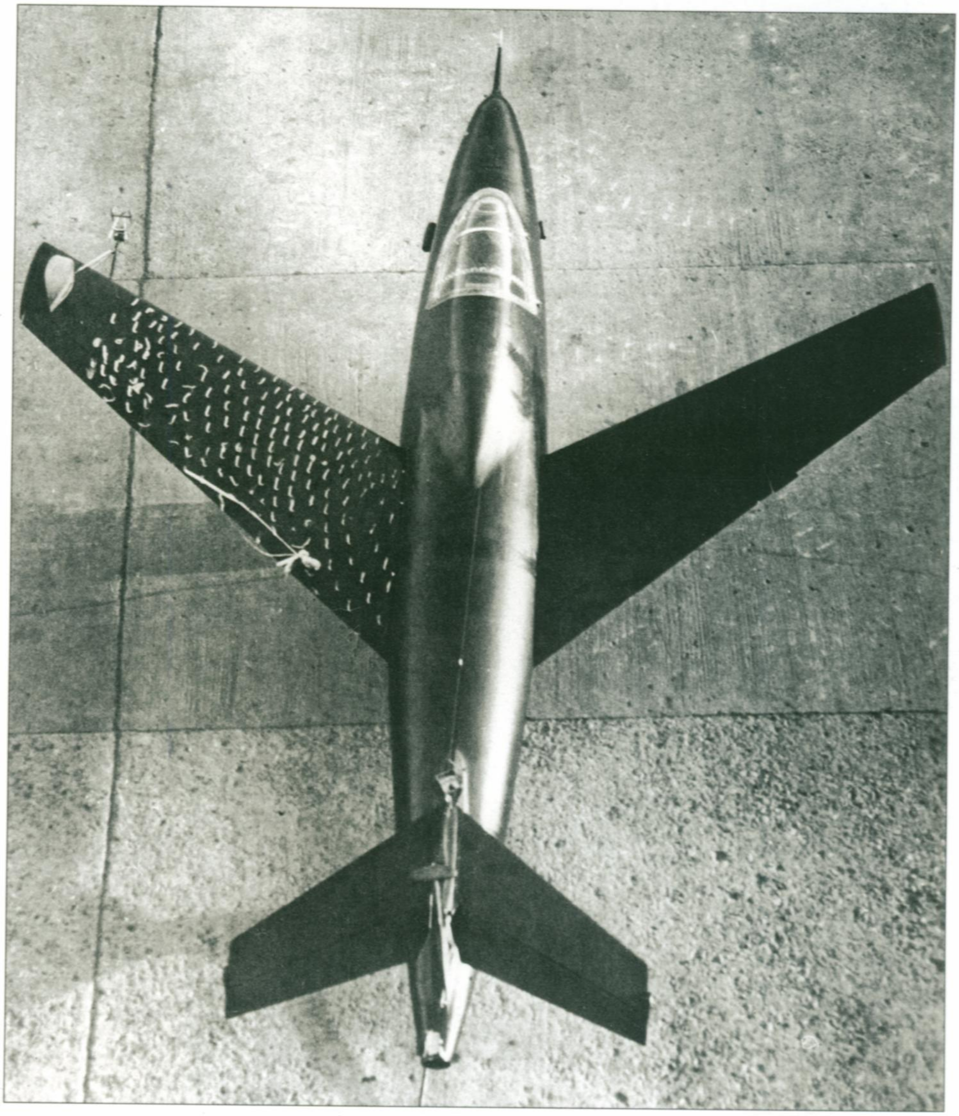
However, the engine designers did not succeed in protecting the pilot against the unreliable operation of the rocket motor on this type of aircraft either. On one occasion an oxidiser pipeline broke during a five-minute flight and noxious nitric acid vapours entered the cockpit, slightly intoxicating the pilot. On 12th September the aircraft began to swing 20° to starboard during the take-off run, and the take-off had to be aborted. The next flight on the programme, which was used for a qualitative assessment of the aircraft's stability and controllability, took place on 20th October.

As mentioned above, the third airframe of I. F. Florov's aircraft ('4303') was to be fitted with the RD-2M3V twin-chamber liquid-fuel rocket motor designed by L. S. Dooshkin which was expected to deliver a thrust of 1,400 kg (3,090 lb). However, the development of this motor became protracted. At the same time, by the summer of 1947 Soviet jet fighter prototypes powered by turbojets already surpassed rocket-propelled aircraft with regard to the main parameters – the flight speed and endurance. In addition, turbojets were much safer in operation than liquid-fuel rocket motors. Therefore further work on Florov's experimental aircraft was terminated.

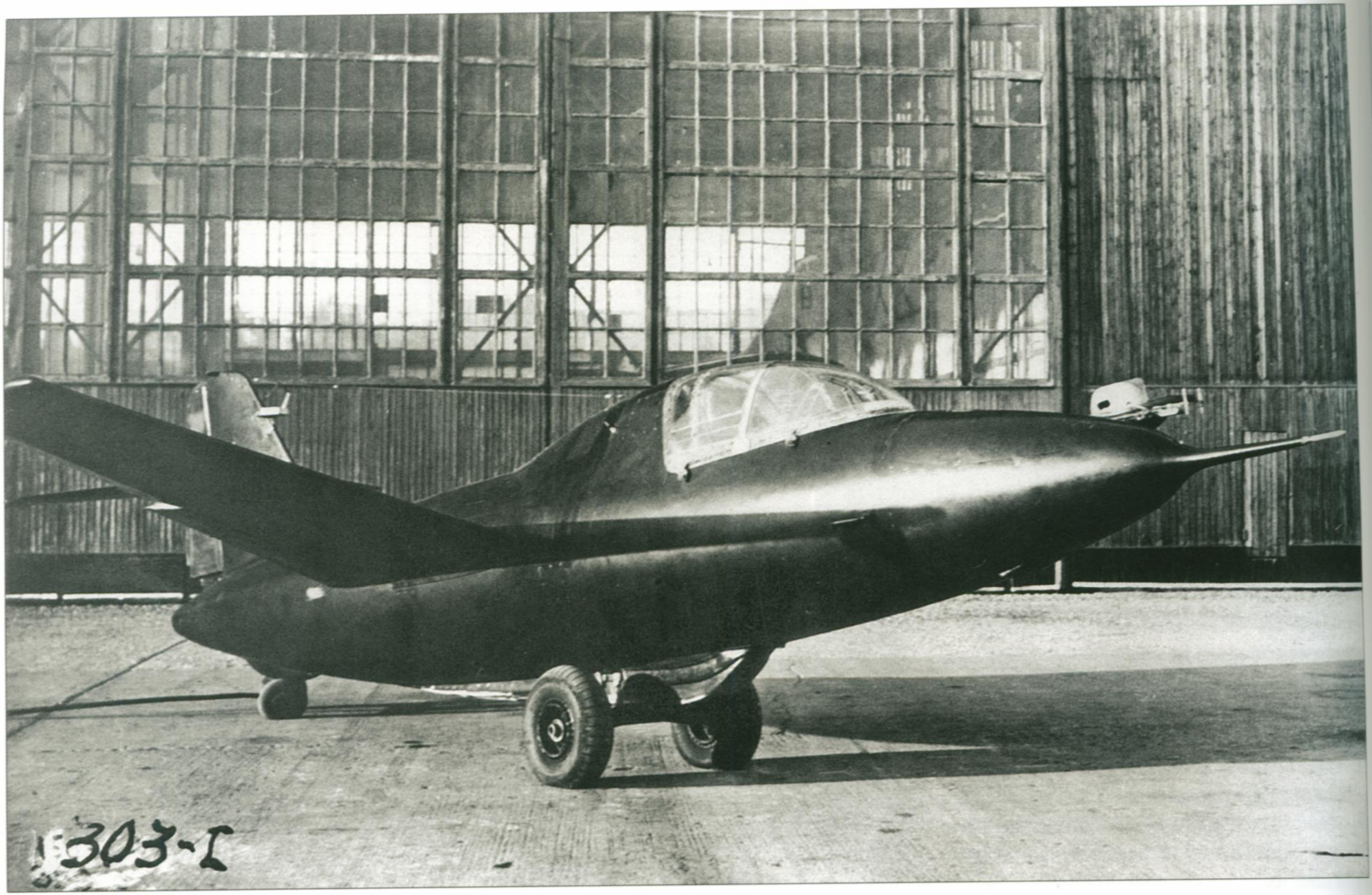
The '4302' Aircraft in Detail

Type: Single-seat experimental aircraft. The airframe was of all-metal construction.

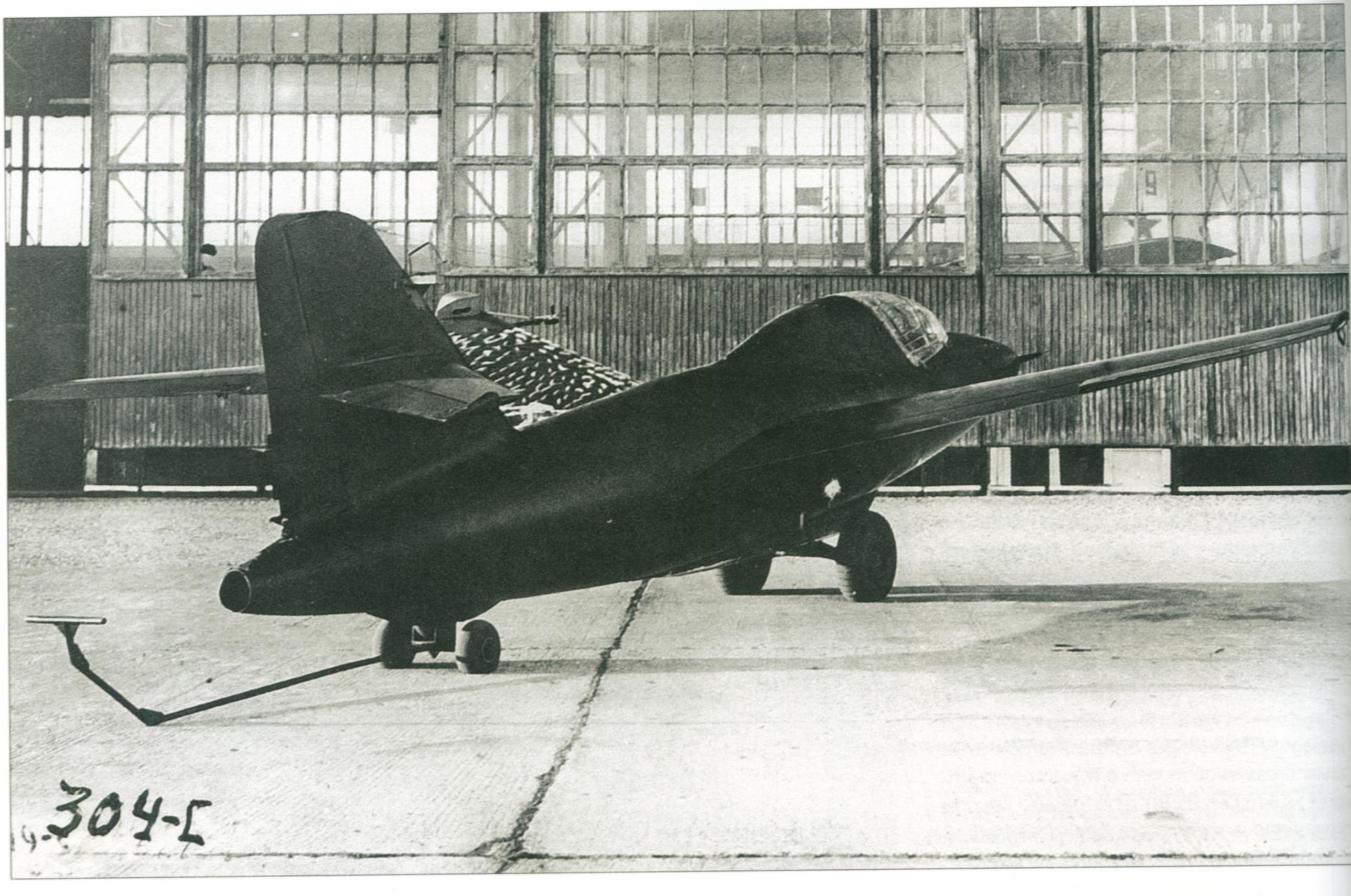
Fuselage: 'Thick' cigar-shaped structure of circular cross-section with a maximum diameter of 1.15 m (3 ft 9¼ in). The forward section incorporated a single-seat cockpit affording good visibility, while the centre section

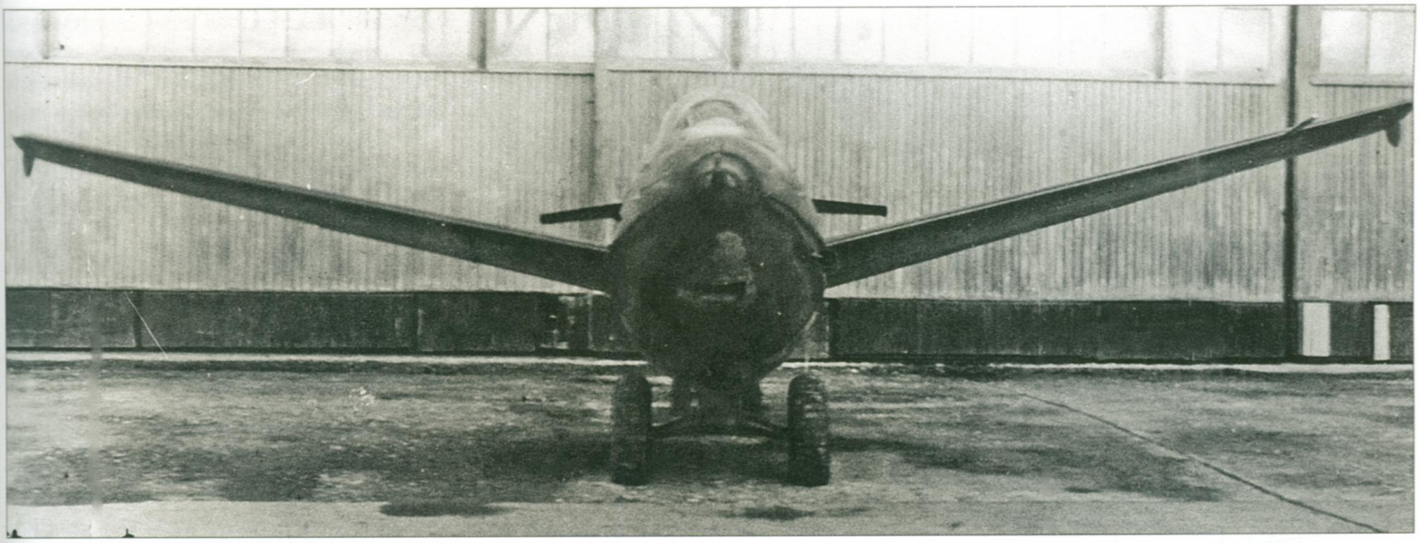


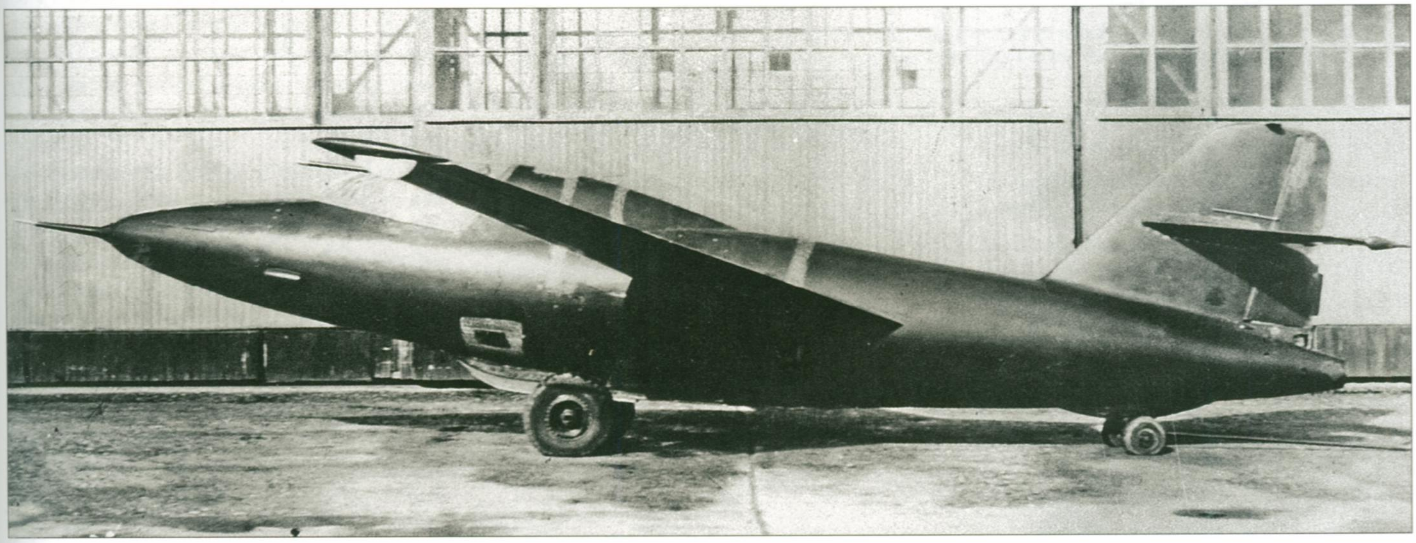
With its forward-swept wings and sweptback horizontal tail, the LL-3 had a highly unusual planform. Note the wool tufts on the port wing and the faired cine camera at the tip recording the airflow pattern.

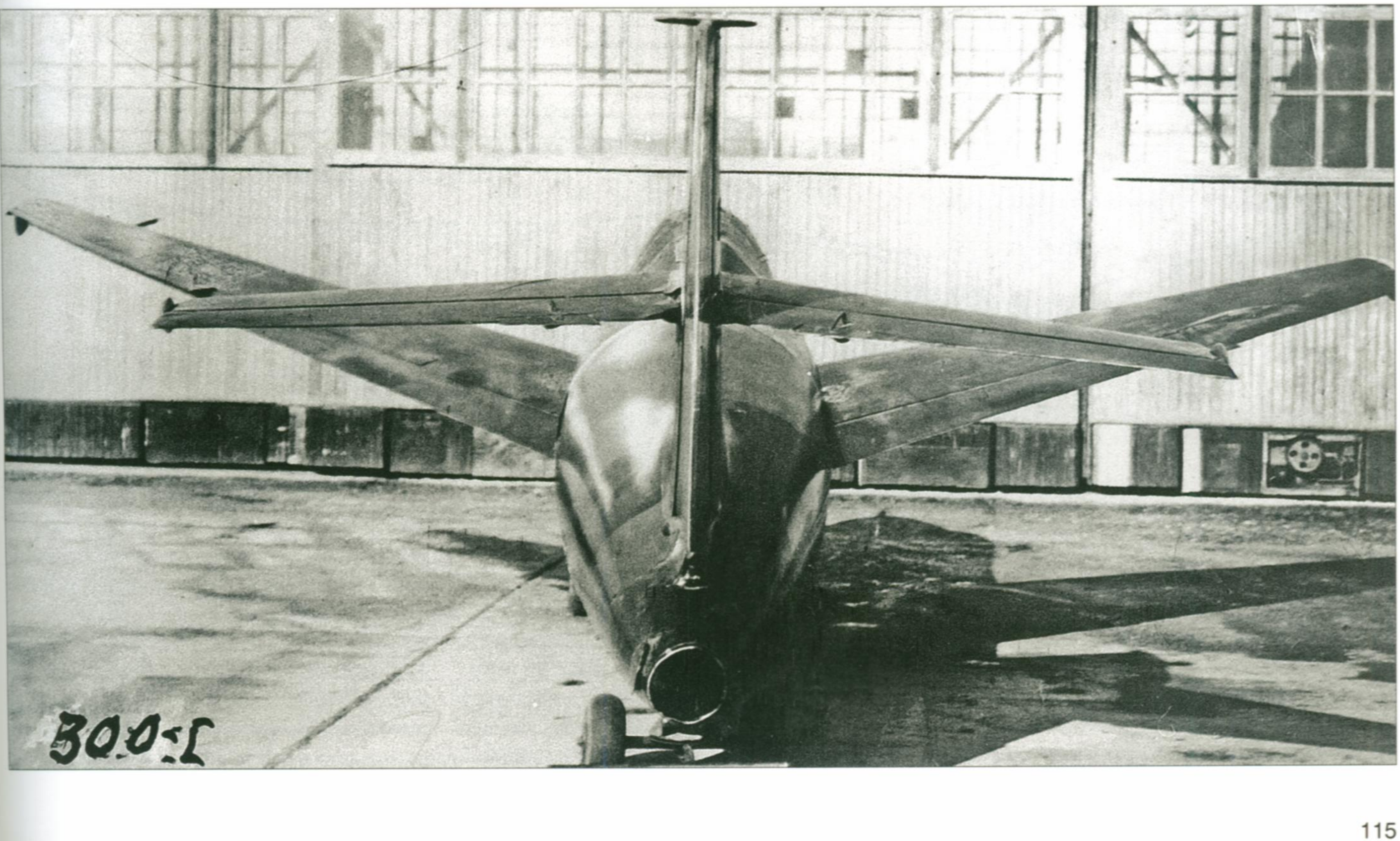


Above, below and opposite page: These views illustrate the LL-3's strong wing dihedral. Note the protective skids under the wingtips, the mounting for a second cine camera on the fin leading edge and the ground handling dolly placed under the rear fuselage.





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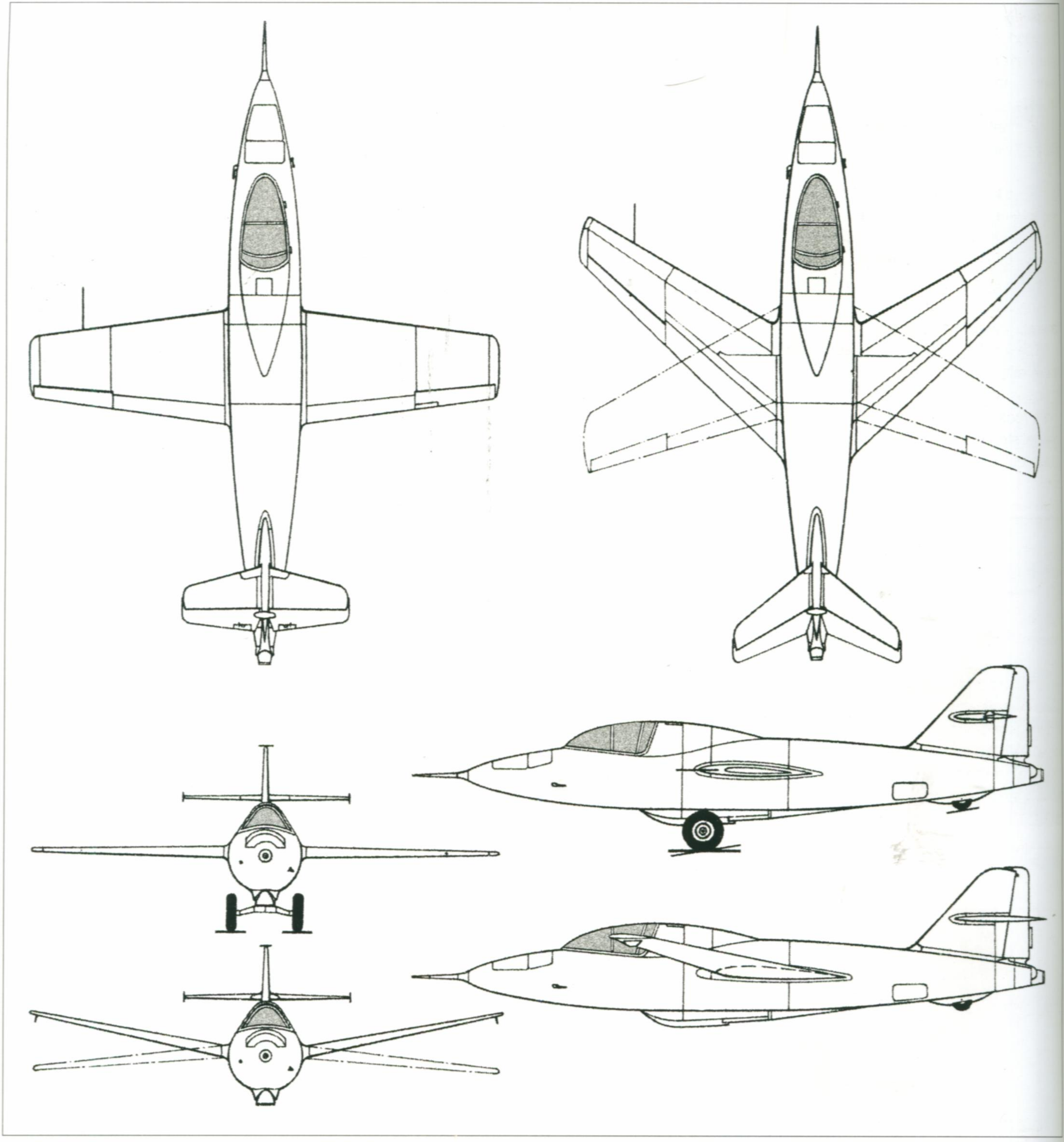


Top: Plan views of the LL-1 (left) and LL-3 (the hatched lines show the LL-2's wing planform). Above: Front and side views of the LL-1 and LL-3 (the hatched lines in the front view show the LL-2's anhedral wings).

accommodated the fuel system; the rocket motor was installed on a tubular mount in the rear fuselage. A towing line lock for unpowered flight was installed beneath the nose.

Wings: Cantilever shoulder-mounted wings built as a one-piece structure; no sweepback, no dihedral. The wings had a constant chord of 1.3 m (4 ft 3 in) and an area of 8.85 m² (95.27 sq ft). The TsAGI 13145 laminar airfoil was used, with a thickness/chord ratio of 13%.

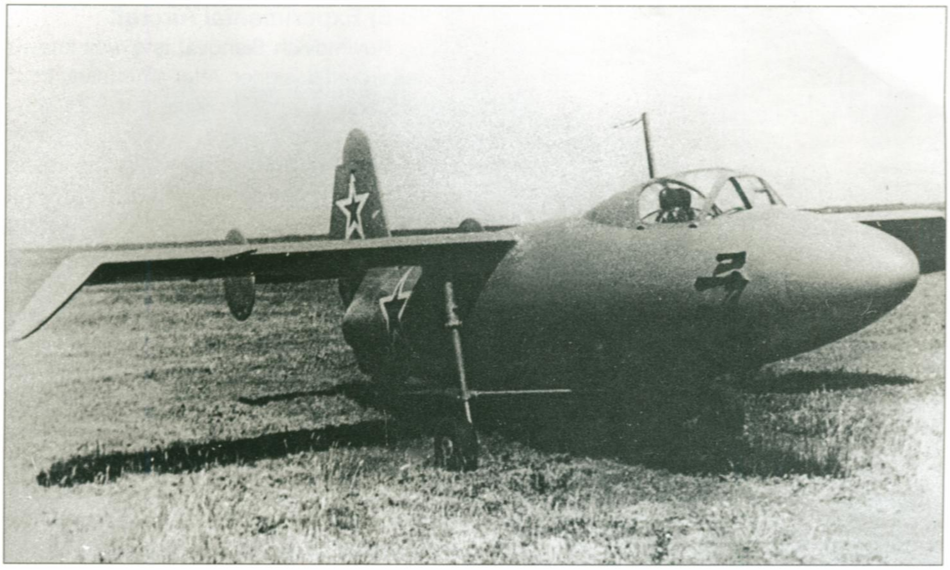
To improve lateral stability and reduce the roll damping effect of the high wing position, the elliptical wingtips were angled down 45° to form so-called 'flippers'. According to the designers' calculations, this, coupled with a small interference of the airflow at the wing/fuselage junction characteristic of a high-wing monoplane, considerably enhanced the aircraft's aerodynamic efficiency. The canted wingtips also serve as wingtip skids when the aircraft completed its landing run. The wing trailing edge was occupied by landing flaps whose outboard sections doubled as ailerons.

Tail Unit: Cantilever conventional tail surfaces. The horizontal tail had a rectangular planform. The vertical tail comprised a fin of trapezoidal shape and a rudder; these were supplemented with two circular endplates mounted at the tips of the horizontal tail. The underfuselage supplementary fin incorporated a non-retractable metal wheel with a shock-absorbing strut.

All control surfaces and ailerons sere skinned with metal.

Landing Gear: For the first flights a temporary non-retractable tailwheel undercarriage was used; the three-strut pyramidal main units were fitted with wheels from the La-5 fighter. Later, the aircraft was fitted with a retractable landing skid, a tail bumper and a jettisonable take-off/ground handling dolly.

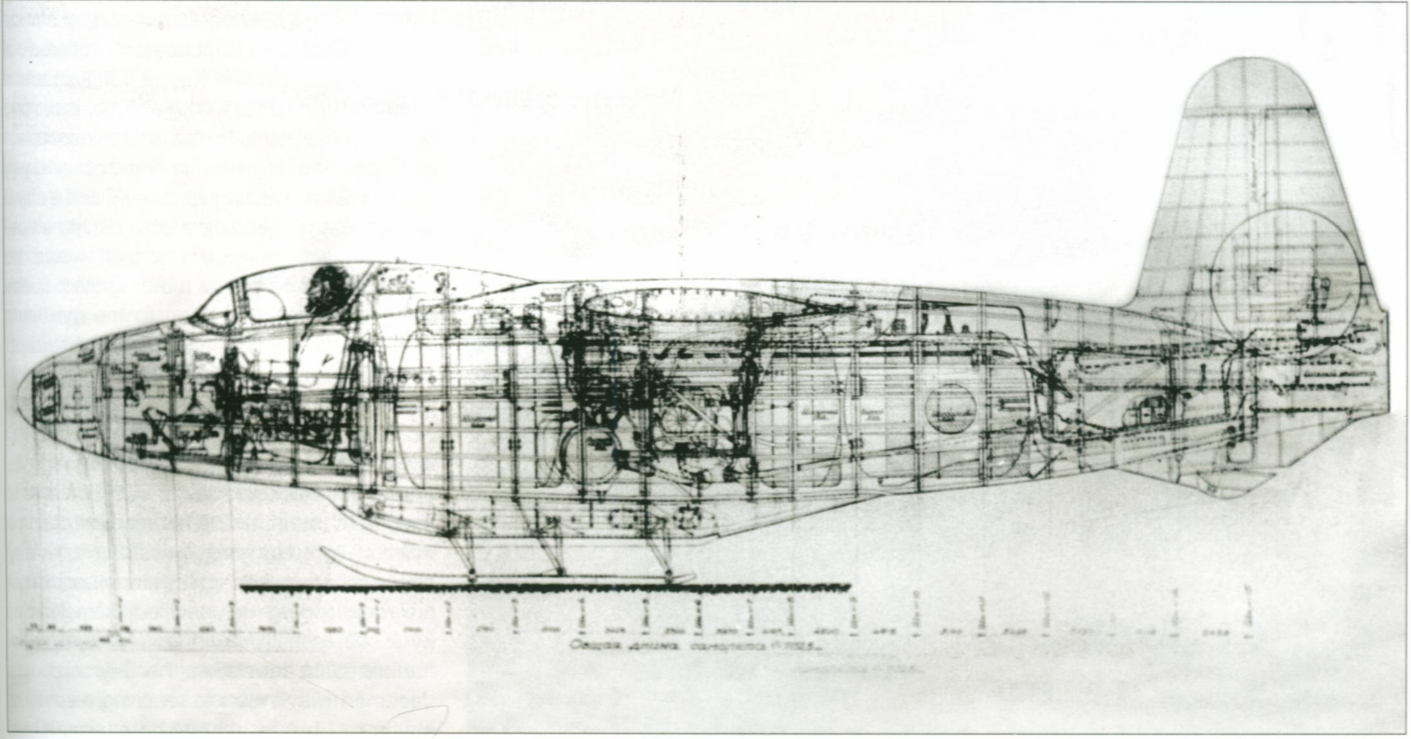
The landing skid was made of riveted duralumin with an external casing made of stainless steel. Two cavities for the attachment rods of the dolly were riveted into the central structural member of the skid. The tricycle dolly was made of two welded steel tubes placed at right angles to each other. The single mainwheels measured 650 x 200 mm (25 x 7.87 in); they were provided with twin-chamber disc brakes. The twin castoring 400 x 150 mm (15.74 x 5.9 in) nosewheels were equipped with a viscous shimmy damper. The dolly was attached to the skid by means of locking hooks. To reduce the dolly's ground run after being jettisoned, it was provided with a braking system which was actuated automatically after the hooks snapped open. The dolly was jettisoned simultaneously with the retraction of the skid, which lay flat against the fuselage when retracted. The skid was provided with a hydraulic shock absorber.



The Florov '4302' rocket-powered aircraft as originally flown (with a fixed tailwheel landing gear and no rocket motor). The main gear struts were modified stock items taken from a Lavochkin La-5 fighter.

Specifications of the '4302' Aircraft

Powerplant	One liquid-fuel rocket motor designed by A. M. Isayev
Thrust, kgp (lbst)	1,100 (2,425)
Length	7.152 m (23 ft 5½ in)
Height	3.06 (10 ft 0½ in)
Height	
on ground	2.750 (9 ft 0¼ in)
tail up	3.255 (10 ft 8 in)
Wing span, m (ft)	6.932 (22 ft 9 in)
Wing area, m² (sq ft)	8.85 (95,27)
Maximum all-up weight, kg (lb)	2,398 (5,288)
Maximum speed, km/h (mph)	520 (323)



A cutaway drawing of the '4302' in its final configuration with a retractable landing skid and a tail bumper.

Above: Test pilot M. F. Yakoobov, Hero of the Soviet Union. He was the project test pilot of the '4302' aircraft.

'5' (B-5) Experimental Aircraft

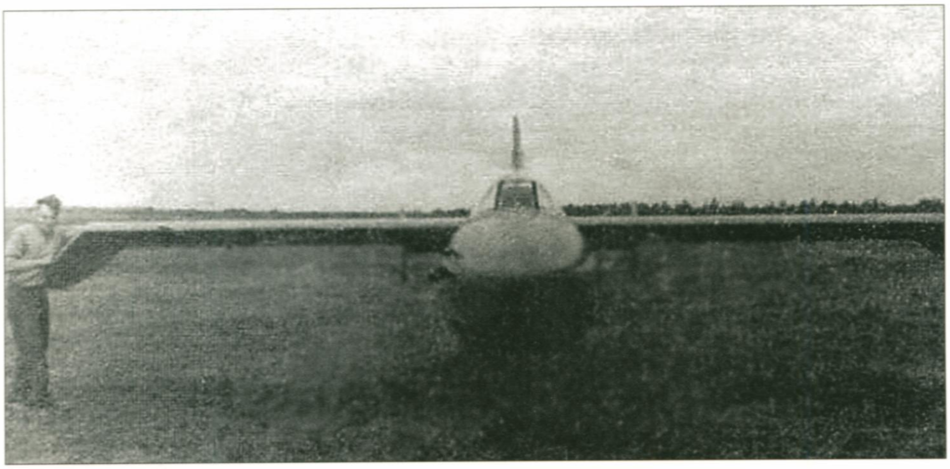
Matus Ruvimovich Bisnovat is a well known Soviet aircraft designer. After graduating from the Moscow Aviation Institute (MAI) in 1931, he occupied a succession of important posts in the Soviet aircraft industry over the years. From 1938 onwards he worked as chief designer of OKB TsAGI (TsAGI's design bureau). In 1942 he was appointed chief of the OKB at plant No.55 subordinated to NII-3 where the '302' rocket-propelled interceptor was under development. In May 1944 the institute was renamed NII-1, and its main task was defined as the development of jet and rocket motors for aircraft. Bisnovat worked at this institute until June 1946; then, together with plant No.293, he established himself as a separate entity outside the framework of the institute and started working on his own.

At that time many specialists in the aircraft industry already realised that, albeit liquid-fuel rocket motors were unsuitable for combat fighter aircraft, they could nevertheless be used on experimental aircraft launched by 'mother ships' for attaining extremely high speeds in short-duration flights. That was the path followed by the USA in the second half of the 1940s – American designers had developed special experimental aircraft powered by liquid-fuel rocket motors, the Bell X-1 and Douglas D-558-II Skyrocket, on which the sound barrier was overcome for the first time. This promising, albeit extremely risky path of development could not be neglected in the Soviet Union, either.

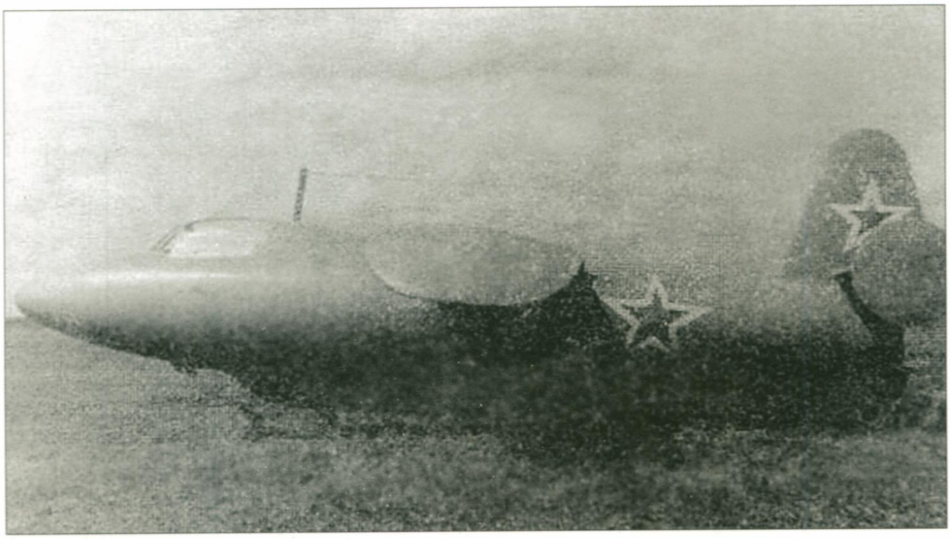
In the passages devoted to the preceding aircraft it was mentioned that Mikhail V. Khrunichev, the Minister of Aircraft Industry, was unwilling to make a concession to the chiefs of NII-1 and the designers of the '4302' aircraft (V. F. Bolkhovitinov and I. F. Florov) and allow them to continue the work on this experimental aircraft. However, there was also a more weighty reason for that – after all, a completely different machine was needed by then. Into the bargain, this was an excellent opportunity to cut the unwelcome authors of complaints down to size and transfer the work to a man who already had much experience in developing rocket-propelled aircraft. Therefore it was decided to form a new OKB headed by M. R. Bisnovat at Plant No.293, where Bolkhovitinov had previously worked as chief designer.

Bisnovat was tasked with building an experimental aircraft featuring a new aerodynamic layout, the purpose being to explore the properties of this layout in flight and master the piloting techniques at speeds of up to Mach 1.1. Known in-house as *izdeliye* '5' (and sometimes also referred to as the B-5 – that is, Bisnovat-5), the aircraft was to feature a promising aerodynamic layout with wings swept back 45°. The chosen powerplant was the RD-2M3VF rocket motor developed by L. S. Dooshkin. This uprated version (F stands for *for***see***rovannyy*, boosted) offered a normal thrust of 1,610 kgp (3,550 lbst) and a boosted thrust of 2,000 kgp (4,410 lbst); one had to make do with this motor because a more powerful engine simply did not exist yet.

The '5' aircraft was to take off and a climb to 10,000 m (32,800 ft) on tow behind a special towplane; then the aircraft would be released and its rocket motor ignited. It was expected that, in addition to the maximum speed of 1,200 km (746 mph) at an altitude of 12,000-13,000 m (39,360-42,640 ft), which would correspond to Mach 1.13, the aircraft would be able to climb from 10,000 m (32,800 ft) to 15,000 m (49,200 ft) in 68 seconds. Its endurance was expected to be 2.5 minutes at maximum thrust, and 3 minutes flat during a mission flight. However, calculations made by specialists showed that the aircraft was capable of exceeding the specified characteristics by a substantial margin (this is exactly what happened in the USA: the Skyrocket was designed with a view to reaching a speed of Mach 1.4, but in actual fact attained Mach 2.1). To ensure pilot's safety, the '5' aircraft



Above and below: The '4302' in its ultimate configuration with a retractable landing skid. Here it is seen after landing; note the downward-canted wingtips doubling as protective skids.



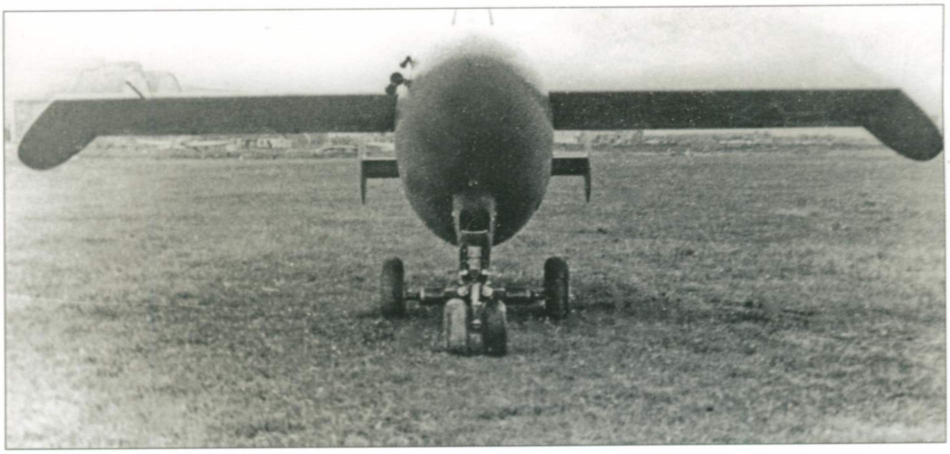
was to be equipped with a pressurised cockpit that could be detached in an emergency, and fitted with air brakes. The requirement for the construction of the new aircraft was formally endorsed by a new prototype aircraft construction plan on 11th March 1947.

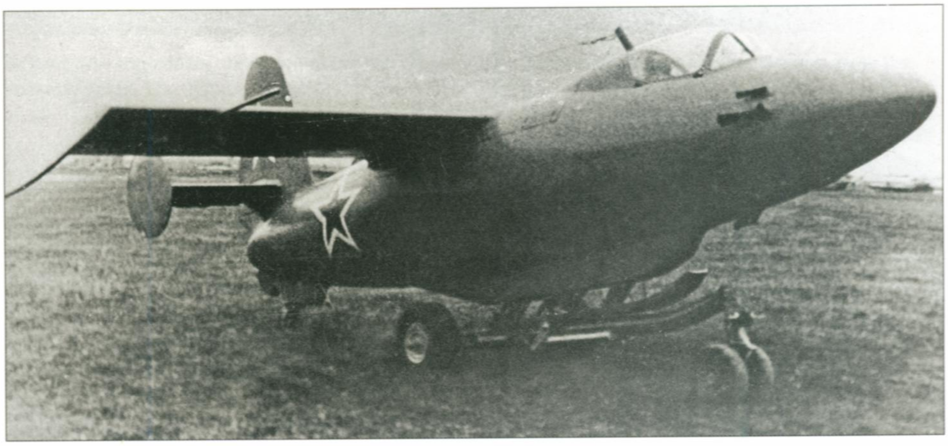
Work on the *izdeliye* '5' proceeded virtually in parallel with the work of German designers at OKB-2 of Plant No.1, even getting a little bit ahead of it. In the USA similar work was being conducted on the Skyrocket aircraft at that time. Despite a number of differences, the '5' (B-5), '346' (DFS 346) and Skyrocket proved to have many similar design features, although their development proceeded completely independently.

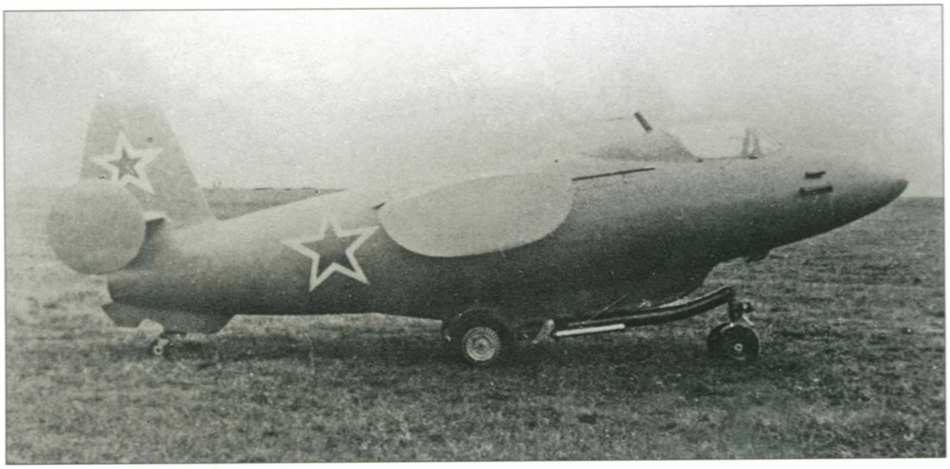
In the course of work on the *izdeliye* '5' the designers built large-scale models fitted with a motor and an autopilot. Preliminary development of the autopilot on one of the models was conducted in the TsAGI T-104 wind tunnel. The launches of these models furnished a large amount of useful information prior to submitting the '5' aircraft for actual flight tests. Among other things, the value of the drag was determined up to a speed corresponding to Mach 1.45.

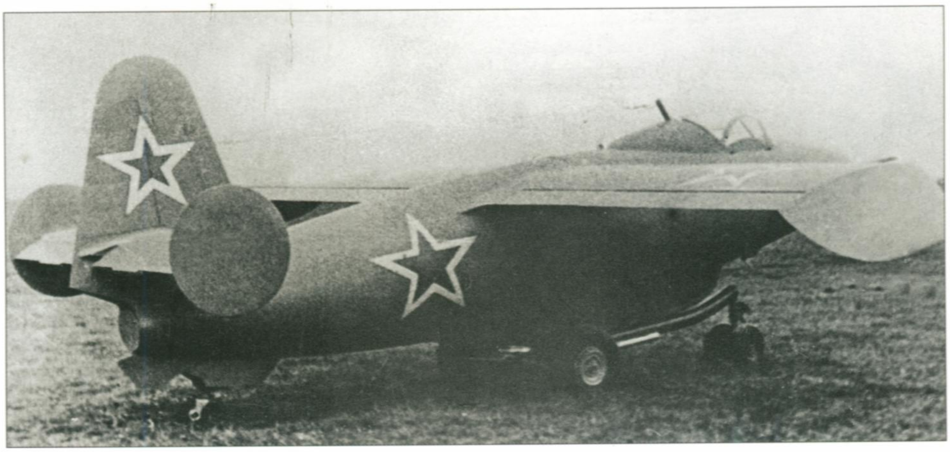
After this the designers decided to continue the research by testing a 1/2.75th scale model of the '5' aircraft in real flight. Within a short space of time such a model was designed and built at Plant No.293 as a joint effort with TsAGI's prototype and experimental production facility, receiving the manufacturer's designation '*izdeliye* 6'. The model was powered by a 400-kgp (880-lbst) Isayev U-400-10 liquid-fuel rocket motor and equipped with an AP-14 autopilot. *Izdeliye* '6' was suspended under a Tu-2 bomber which took it to an altitude of 9,000 m (29,530 ft), where the model was released. According to estimates, in a straight-line free flight with the rocket motor running the model was to attain a supersonic speed (up to Mach 1.225). To capture the flight parameters the model was provided with data recording equipment. Its recovery after the motor shut down was ensured by a fairly complicated automatic parachute system which consecutively deployed two wing-mounted drag parachutes, then the rear drag 'chute with an area of 1 m^2 (10.75 sq ft) and, finally, the main parachute with an area of 100 m^2 (1,076 sq ft).

In September-November 1947 flight tests of four examples of the *izdeliye* '6' were conducted at Goomrak airfield near Stalingrad (now the airport of Volgograd). The first of these, bearing the side number '61' (= *izdeliye* '6' No.1), accelerated very quickly, left behind the 'mother ship' and the La-7 chase aircraft and disappeared out of sight; it was never found subsequently. The second model, marked '62', showed appreciable oscillations around the longitudinal and

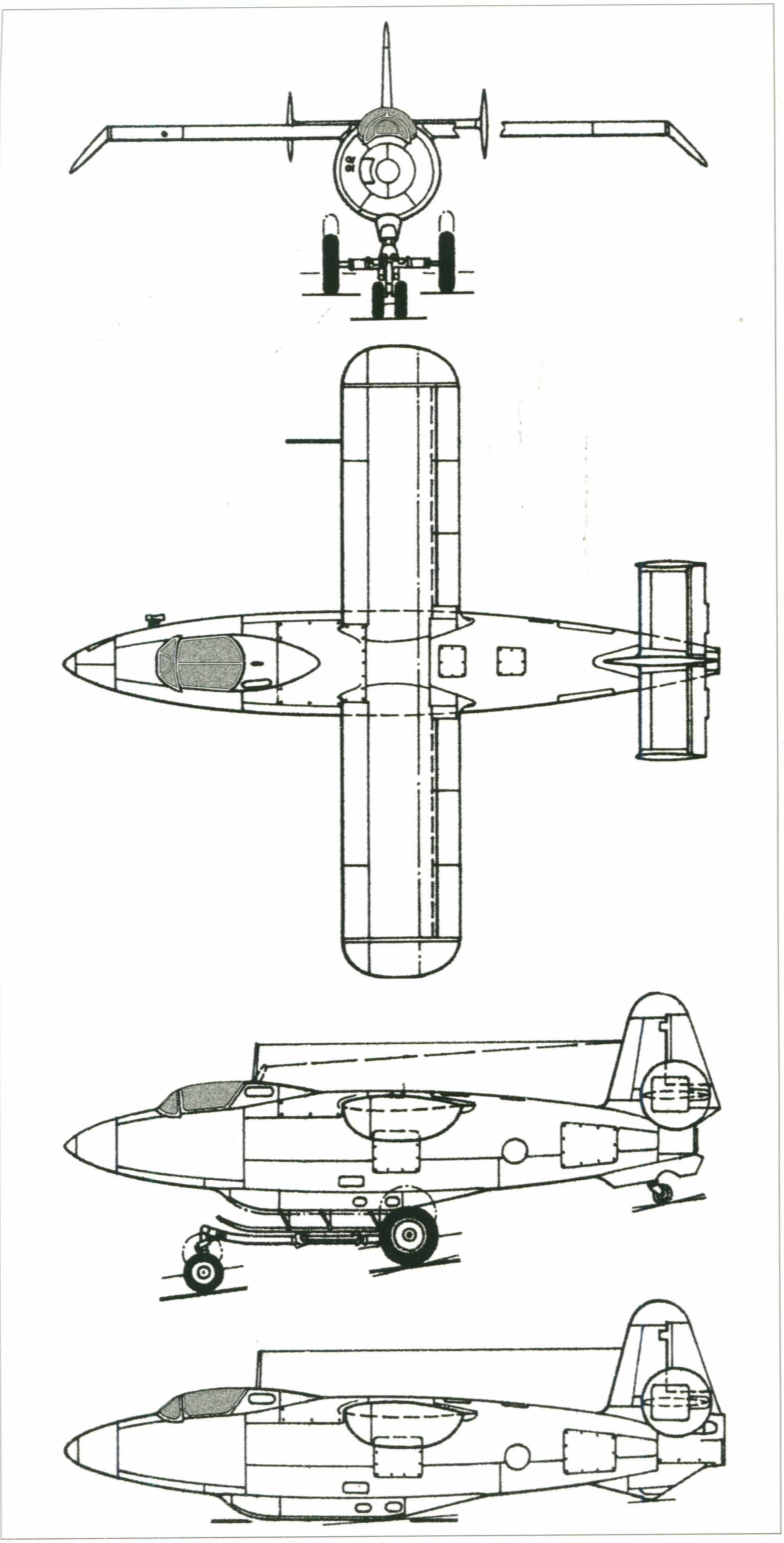








Top, centre and above: With the take-off dolly in place, the '4302' had a marked nose-high ground angle. Note the retractable tailwheel and the blanked-off rocket motor nozzle.



A three-view of the '4302' prototype in its ultimate guise, with an additional side view of the '4303'.

lateral axes after the release and transition to free flight. After the premature shutdown of its motor it landed safely by parachute. The third model ('63') flew well, but after 45 seconds of powered flight it suddenly entered a dive, the brake parachutes were torn off and the model crashed. According to calculations made by the researchers, the vehicle had attained Mach 1.28. The fourth model ('64') performed autonomous flight in the course of 52 seconds with small self-induced oscillations around the lateral axis. After engine shutdown the main parachute failed to deploy and the model was destroyed, too. The test equipment readouts showed that the model had reached a speed of Mach 1.11.

Interestingly, the leaders of MAP had the intention to demonstrate the release of the *izdeliye* '6' models at one of the air events at Tushino. The order issued by the Minister, titled 'On the preparation of aircraft for participation in the Air Display on 18th August 1947', contained the following passage:

'…43. Chief designer and director of Plant No.293 Comrade Bisnovat is to prepare by 15th July two izdeliye *'6' full-size models* (sic) *with Isayev-designed liquid-fuel rocket motors delivering a thrust of 400 kg for the participation in the Air Display…'*

Analysing the results of the *izdeliye* '6' models' tests, MAP specialists concluded that the research based on the use of high-speed models simulating the *izdeliye* '5' had generally been a success. However, the military disagreed with this assessment, since they were wont to doubt the veracity of the data obtained, bearing in mind the loss of data recording equipment during crashes of the models. They even suggested building a further twenty such models in an improved version and repeating the tests – on condition that full preservation of the recorded data was ensured. However, this proved unnecessary because the first full-scale flying prototype of the '5' aircraft was nearing completion.

Izdeliye '5' was an all-metal mid-wing monoplane intended to be suspended under a carrier aircraft; it had wings with 45° sweepback at quarter chord. One boundary layer fence was installed on the upper surface of each wing to prevent an early onset of tip stall. The cockpit, whose canopy was completely faired into the fuselage contours, was pressurised and fitted with an ejection seat.

The choice of wing airfoils was made in accordance with recommendations issued by TsAGI. The strong sweepback angle necessitated providing the wings with considerable anhedral (5°) in order to ensure adequate lateral stability. Subsequently, in the course of testing, it became obvious that this angle was too small for ensuring the required stability and control characteristics. The wings were built as a one-piece assembly; this was dictated by the high requirements concerning the rigidity of the structure because of the necessity to prevent deformations that could arise in flight at supersonic speeds. The aircraft was equipped with airbrakes whose deployment angle was variable; this feature greatly simplified the calculation of the landing approach.

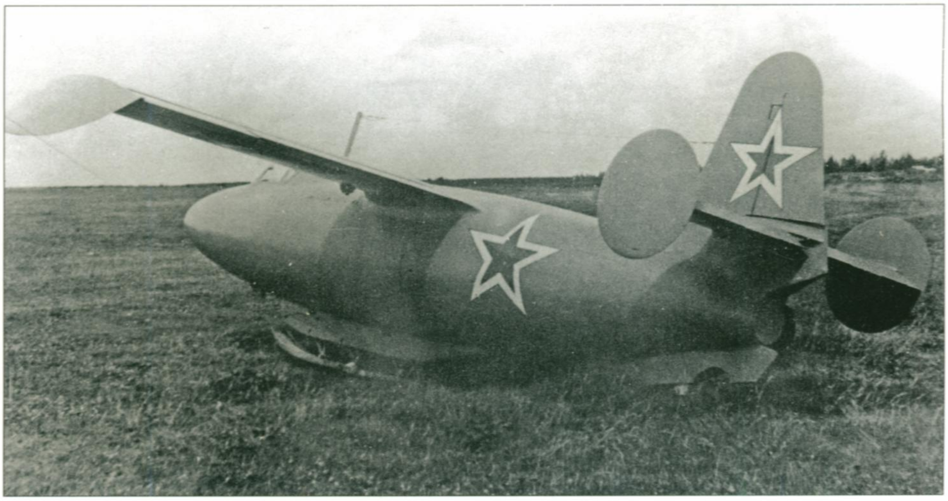
As planned, *izdeliye* '5' was fitted with an RD-2M3VF twin-chamber liquid-fuel rocket motor. The amount of propellants (kerosene and nitric acid) and of the hydrogen peroxide used for feeding the turbopump unit were sufficient to allow the motor to run for two minutes at full thrust. The aircraft's design all-up weight was 3,184 kg (7,020 lb), the empty weight being 883 kg (1,947 lb).

The boosted version of the rocket motor for the '5' aircraft was not delivered on schedule; for this reason the first example of the 'five' did not enter testing before July 1948. It was decided to use a Petlyakov Pe-8 heavy bomber powered by four Shvetsov ASh-82FN radials as the carrier aircraft. A special pylon was mounted under its starboard wing between the fuselage and the No.3 engine nacelle for carrying the '5' aircraft. In the course of flight tests the 'five' was lifted to an altitude of 7,000-7,500 m (22,960-24,600 ft).

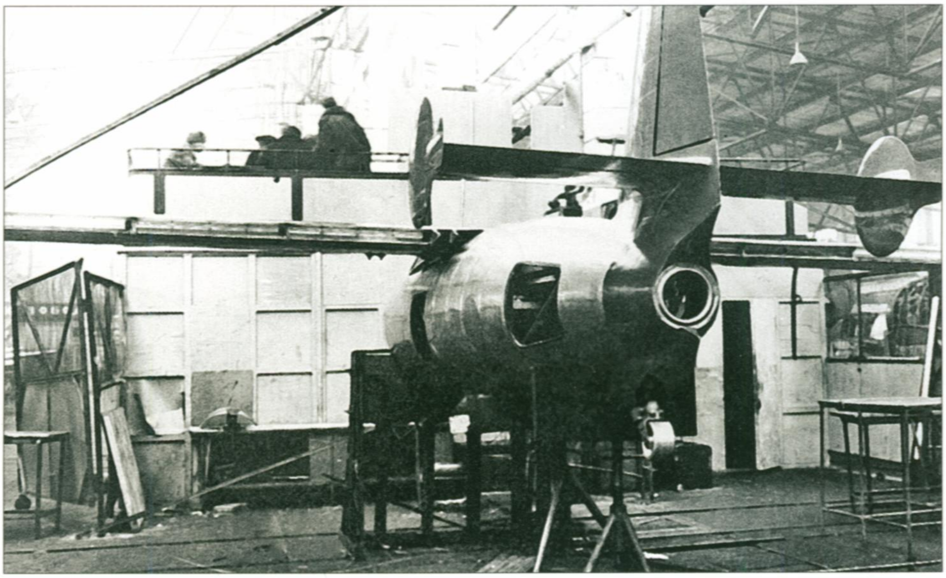
A. K. Pakhomov, who had been promoted to Lieutenant-Colonel by then, was appointed project test pilot; he had already obtained the experience of flights on the aforementioned '4302' rocket-powered aircraft. The 'mother ship', Pe-8 c/n 42911, was piloted by M. A. Samusev and B. V. Zemskov. In keeping with what had already become a tradition (in actual fact this was, of course, not a tradition but a necessity) it was decided to test the aircraft in a glider configuration first and then proceed to powered flights. All flights of the '5' aircraft in glider configuration followed the same pattern: first, a dive followed by recovery to level flight, the aircraft pulling 2-3 Gs, then a deceleration right down to a full stall, whereupon the aircraft would accelerate, recover and perform manoeuvres specified in the mission plan. At an altitude of 1,500-2,000 m (4,900-6,600 ft) fulfilment of the mission was terminated and the aircraft commenced the landing approach.

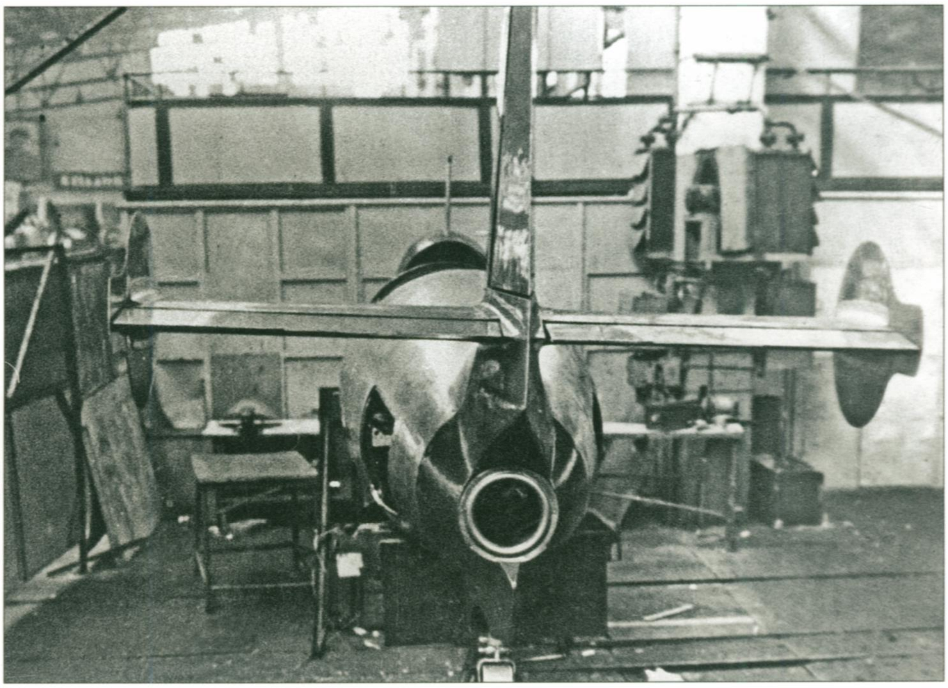
The maiden flight of the first prototype (designated '5-1') took place on 14th July 1948. As it fell away from the 'mother ship', the experimental aircraft struck a bracing strut of the suspension pylon, damaging the wing skin; this resulted in a partial jamming of the elevators. Nevertheless, the pilot managed to make an off-field landing; in so doing the '5-1' suffered considerable damage and was sent to the plant for repairs.

In the course of the repairs the first prototype underwent a number of revisions. To ensure reliable separation and prevent a

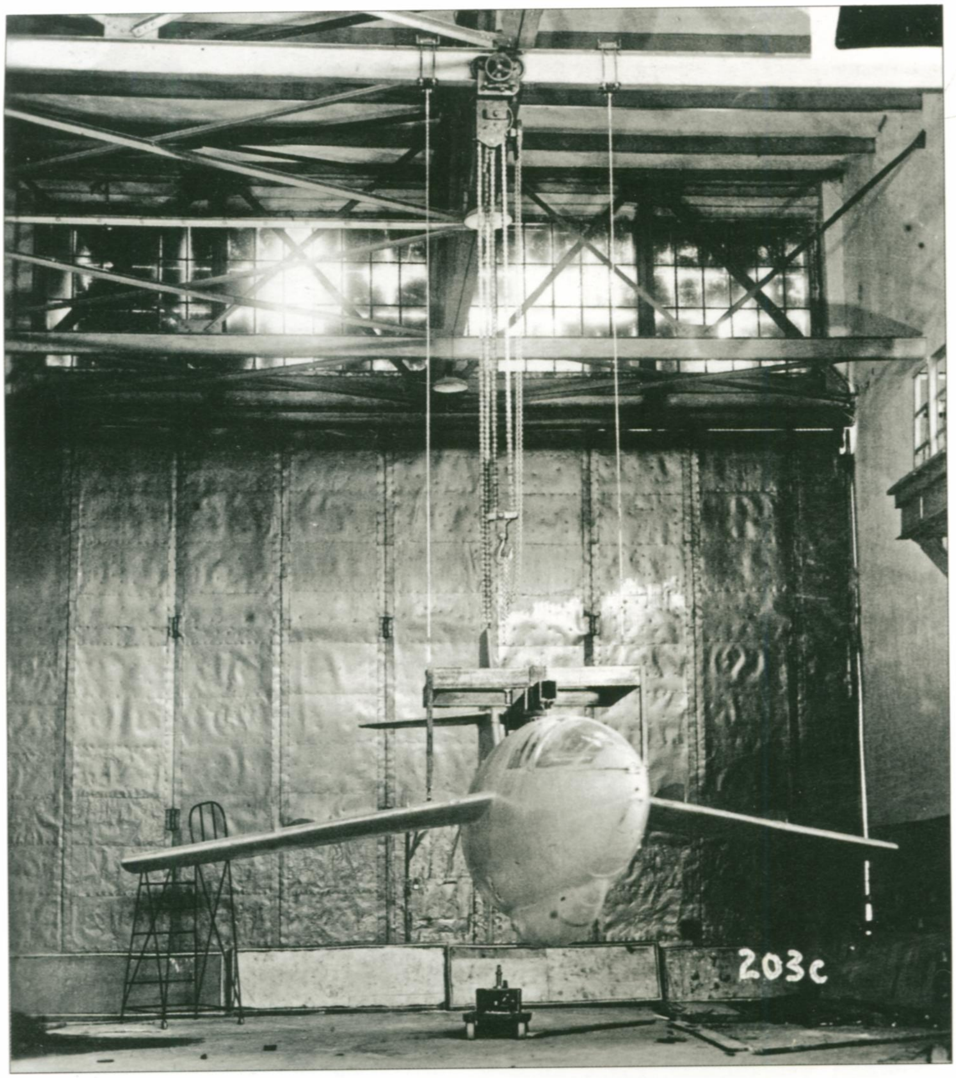


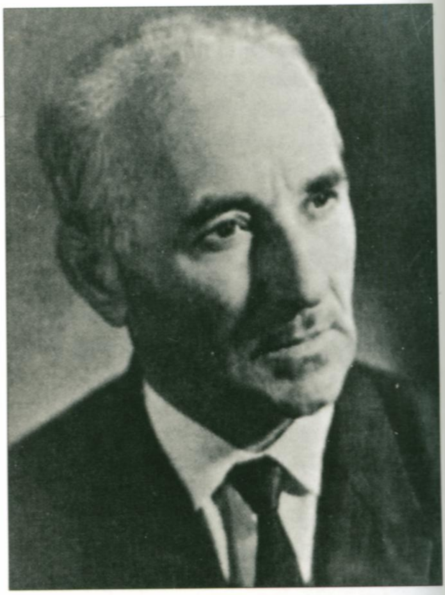
Above: The engineless '4302' prototype has tipped over onto its starboard wing after landing. Note the extended skid. The circular endplate fins are clearly visible.





Top and above: Another example of the '4302' in varying degrees of completion at aircraft factory No.21 in Gor'kiy. Note the revised shape of the endplate fins with an excrescence at the rear.

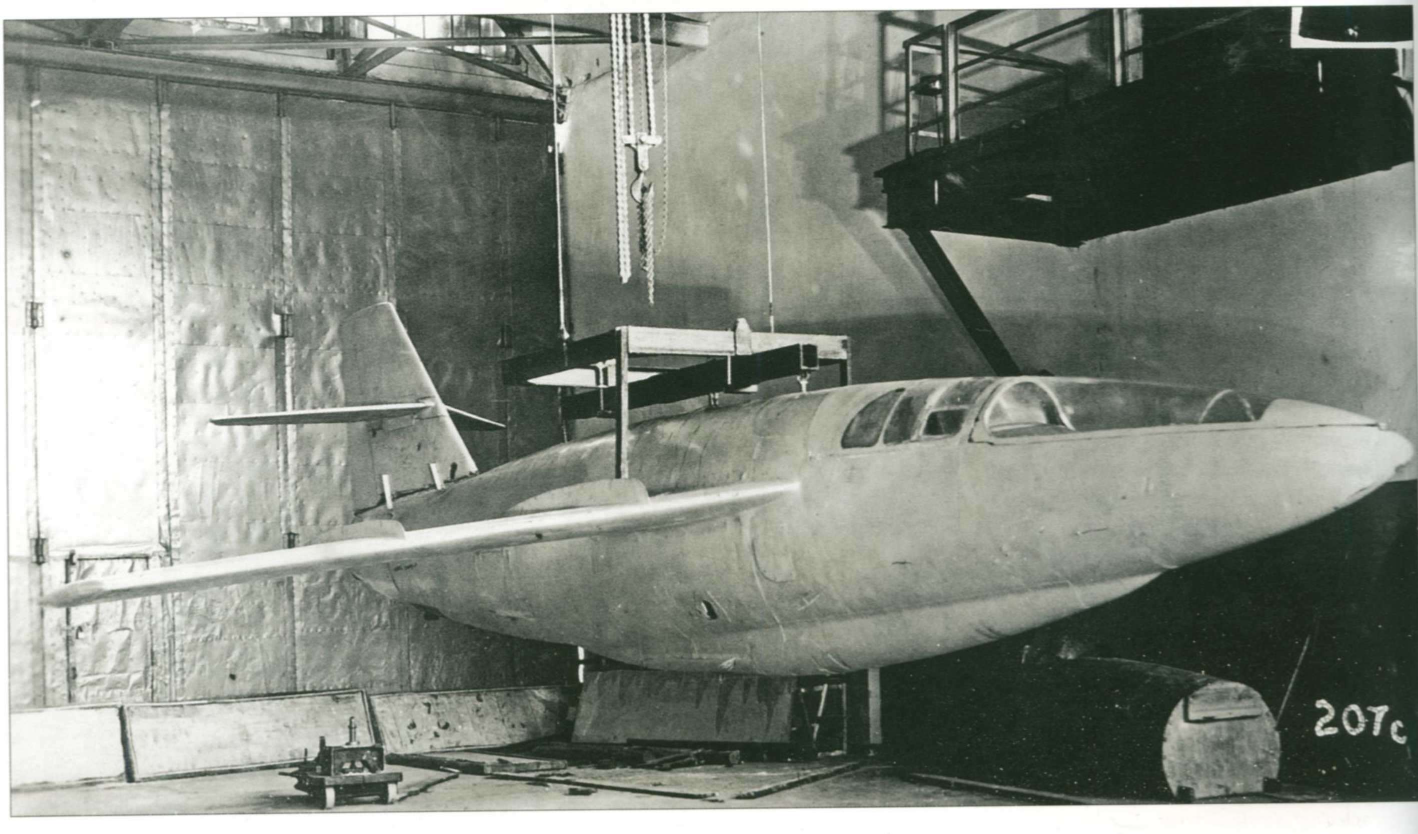


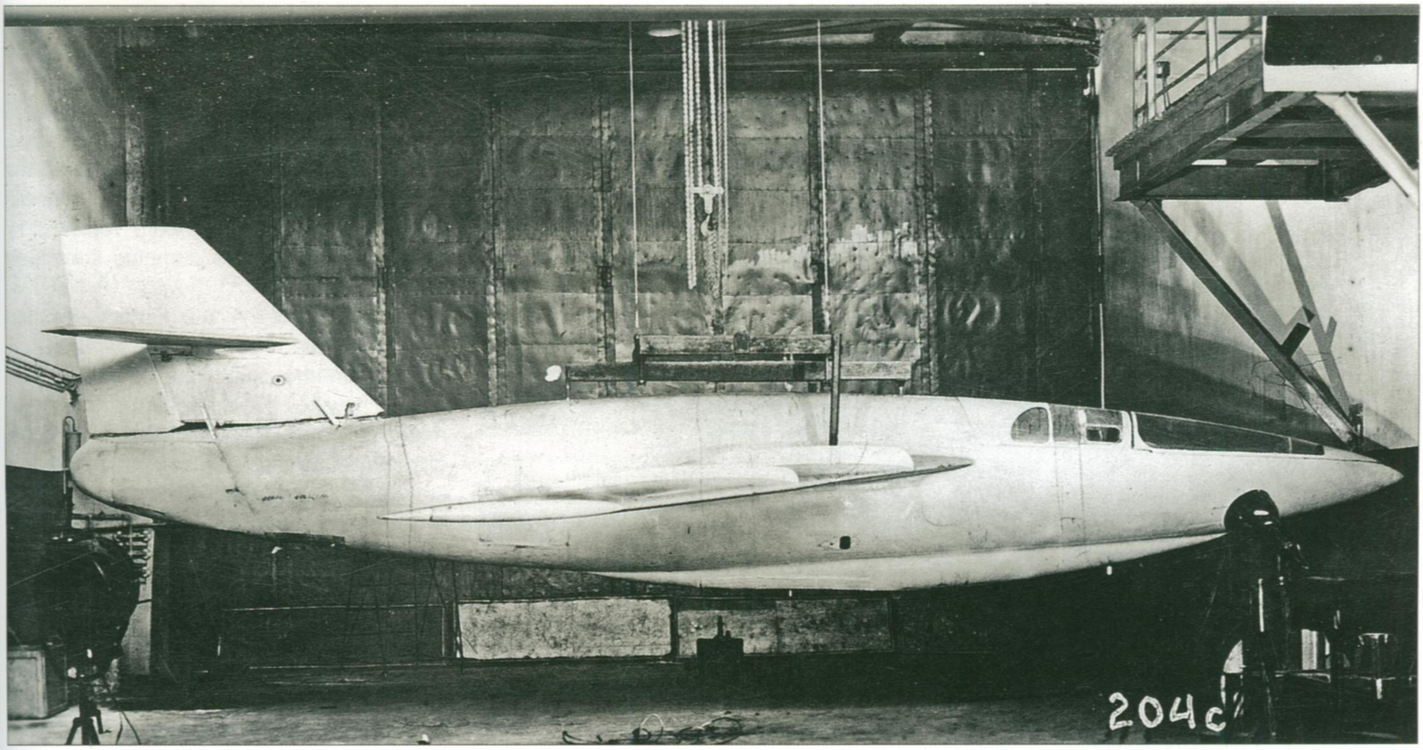


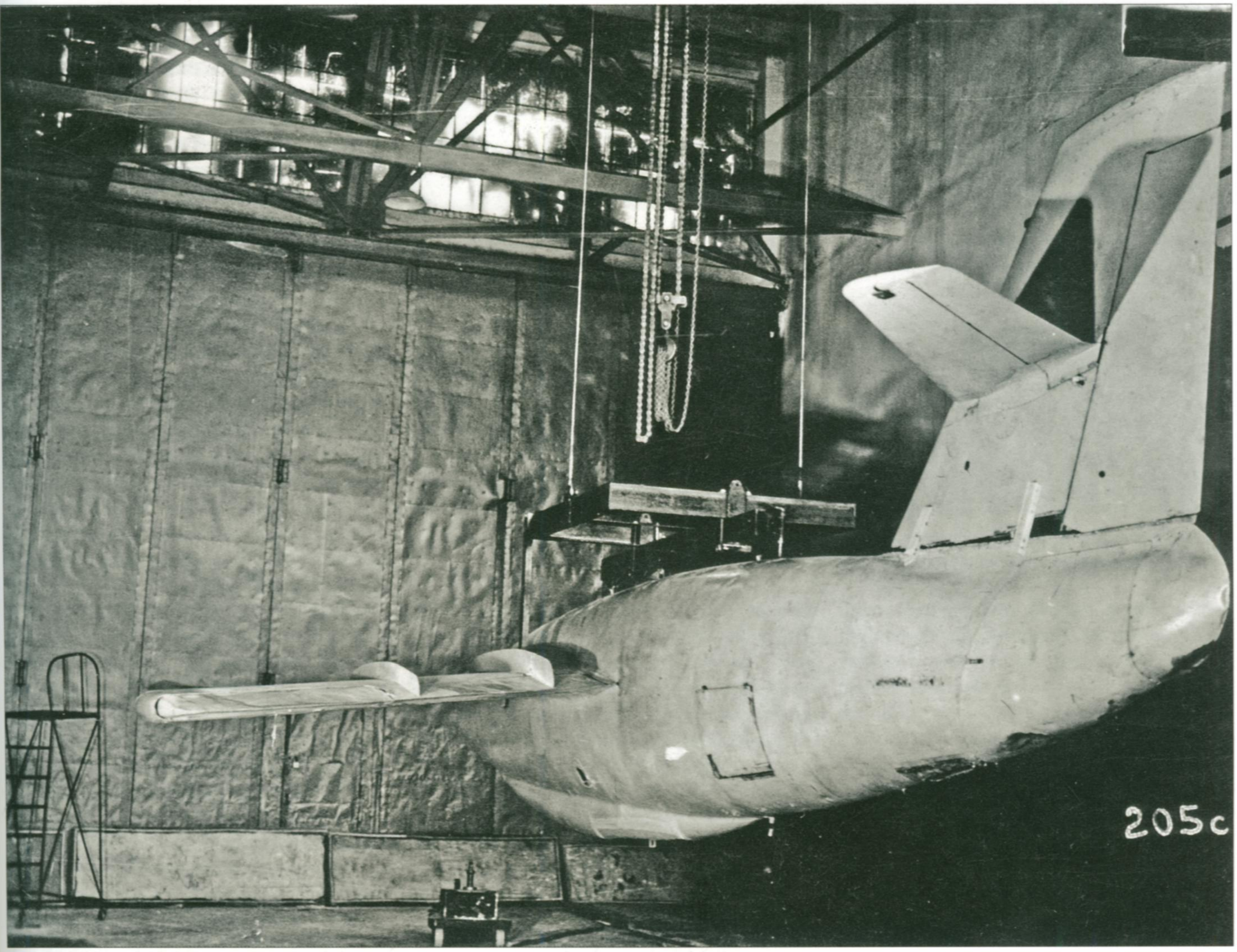
Above: Chief Designer of OKB-293 Matus R. Bisnovat.

recurrence of the collision with the 'mother ship', the attitude of the 'five' relative to the Pe-8's longitudinal datum line was changed from 0° to –4°. Changes were also made to the control system, which subsequently functioned reliably.

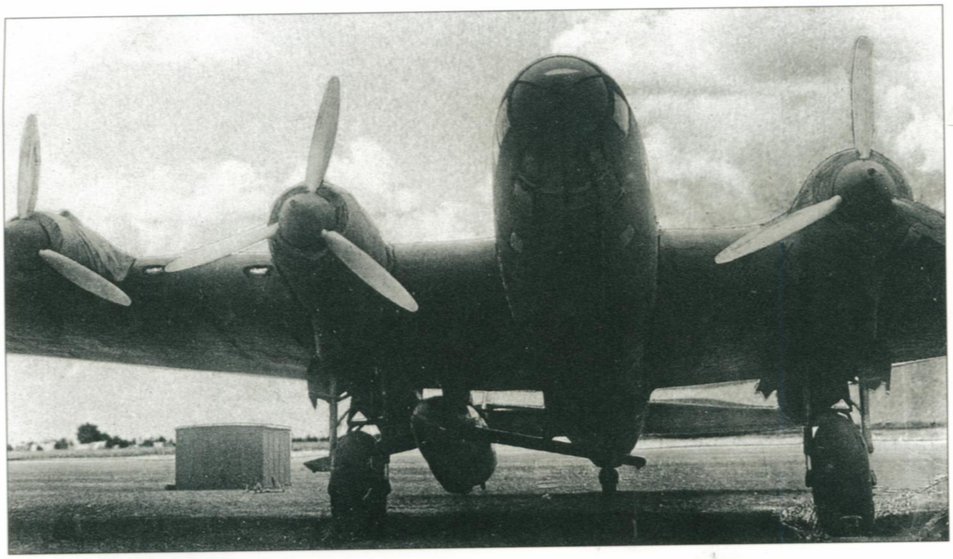
The second flight involving a release from the Pe-8 took place on 3rd September. It passed in a more satisfactory way, but the *izdeliye* '5' was found to suffer from lateral instability; the aircraft banked spontaneously to both sides, the aileron authority being insufficient to counteract the roll. It was



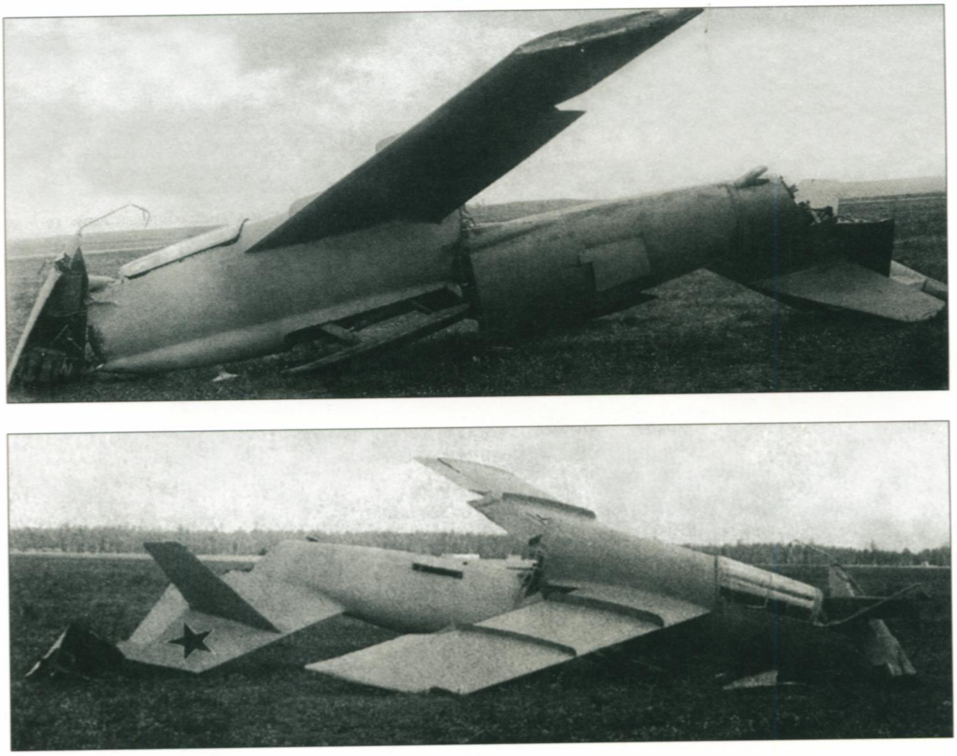




This page and opposite page: The izdeliye '5' (B-5) research aircraft undergoing static tests at TsAGI. Note the canopy design, the lateral airbrakes and the tail fairing replacing the rocket motor nozzle. The L-section profiles at the base of the fin were probably a temporary measure.



Above: The Pe-8 4M-82 carrier aircraft (c/n 42911) with the B-5 prototype ('5-1') suspended; note that the B-5's starboard wing is aft of the Pe-8's main gear unit.



Top and above: The wreckage of the '5-1' following its crash landing on 5th September 1948. Test pilot A. K. Pakhomov walked away but the aircraft was a total loss.

decided to study this phenomenon more closely in the third flight on 5th September, but the landing resulted in a new accident. After the touchdown a minor lateral oscillation developed into a violent swinging from side to side, which the pilot was unable to counter. The aircraft plunged into the runway in a nose-down attitude, breaking its back aft of the wings. The pilot was unhurt, but the '5-1' was damaged beyond repair.

According to the conclusion of the accident investigation board presided over by deputy chief of a TsAGI laboratory V. N. Matveyev, the accident was caused by a combination of insufficient lateral stability at low speeds with the flaps deployed, excessive friction in the aileron control circuit, an incorrect landing approach and a partially restricted view from the cockpit because the glazing had misted up. It was recommended that a second prototype free from these deficiencies be manufactured. In addition, TsAGI suggested replacing the protective bows under the wingtips with outrigger skids and testing the B-5 in the T-101 wind tunnel permitting the testing of full-size aircraft.

The loss of the first prototype caused a delay in the testing. The flights did not resume until January 1949, when the second example – the '5-2' aircraft – was completed. Structurally it was almost identical to the '5-1', yet it incorporated a few modifications. Among other things, the sweepback angle and the aspect ratio of the vertical tail were increased to improve directional stability and its contours were changed, which increased the overall length. As per TsAGI recommendations the wingtip bows were replaced by shock-absorbing skids damping the impact at touch-down.

The flights of the '5-2' aircraft were performed by test pilot Gheorgiy M. Shiyanov, the Pe-8 'mother ship' was piloted by Gintse and Chistyakov. The first flight of the new machine took place on 26th January 1949, but it ended in a landing beyond the runway; the '5-2' was damaged and needed repairs. The imprecise landings of the '5-1' and '5-2' were caused primarily by the difficulty of calculating the glide path (especially in the first flight) because of the all-too-short runway which LII had at its disposal at the time.

In the process of repair the '5-2' was subjected to further improvements. The landing skid was mounted parallel to the aircraft's longitudinal datum line; this made the landing run more stable and made it possible to dispense with the tail skid. Later a ventral fin was added at the tail skid's former location to improve directional stability. Upon completion of the repairs of the '5-2' Shiyanov made a second flight which ended without trouble.

Analysis of the results of the two flights showed that the required balance of lateral and directional stability had not yet been achieved. In an effort to improve it, the designers hit upon an ingenious solution: they fitted the wings with so-called 'flippers' which produced an effect similar to the one caused by changing the wing dihedral (since the wings were an integral structure, it was impossible to alter the wing dihedral). The 'flippers' were airfoil-shaped surfaces attached to the wingtips and canted downwards 45°; they increased the wing span to 6.6 m (21 ft 8 in). The lower edges of the 'flippers' were reinforced, enabling them to act as outrigger skids on which the aircraft rested at the end of its landing run.

After all the modifications had been effected, G. M. Shiyanov performed several more flights in the '5-2'. Between 26th January and 9th June 1949 the machine made nine gliding flights, followed by a further four flights in October and November, but the permission to perform a powered flight never came. The weight of the second prototype in its first flights was 1,710 kg (3,770 lb), and the maximum speed attained in a dive from 5,400 m (17,700 ft) corresponded to Mach 0.775. The aircraft showed satisfactory handling. Controlling the aircraft with the help of irreversible hydraulic actuators virtually did not differ from the conventional manual control mode. All systems were properly adjusted and the aircraft was ready for flights with the rocket motor in operation; however, a decision was taken to halt further work.

The testing of the '5' aircraft, undoubtedly, made its contribution to the exploration of the idiosyncrasies of swept-wing aircraft.

'5' (B-5) Aircraft in Detail

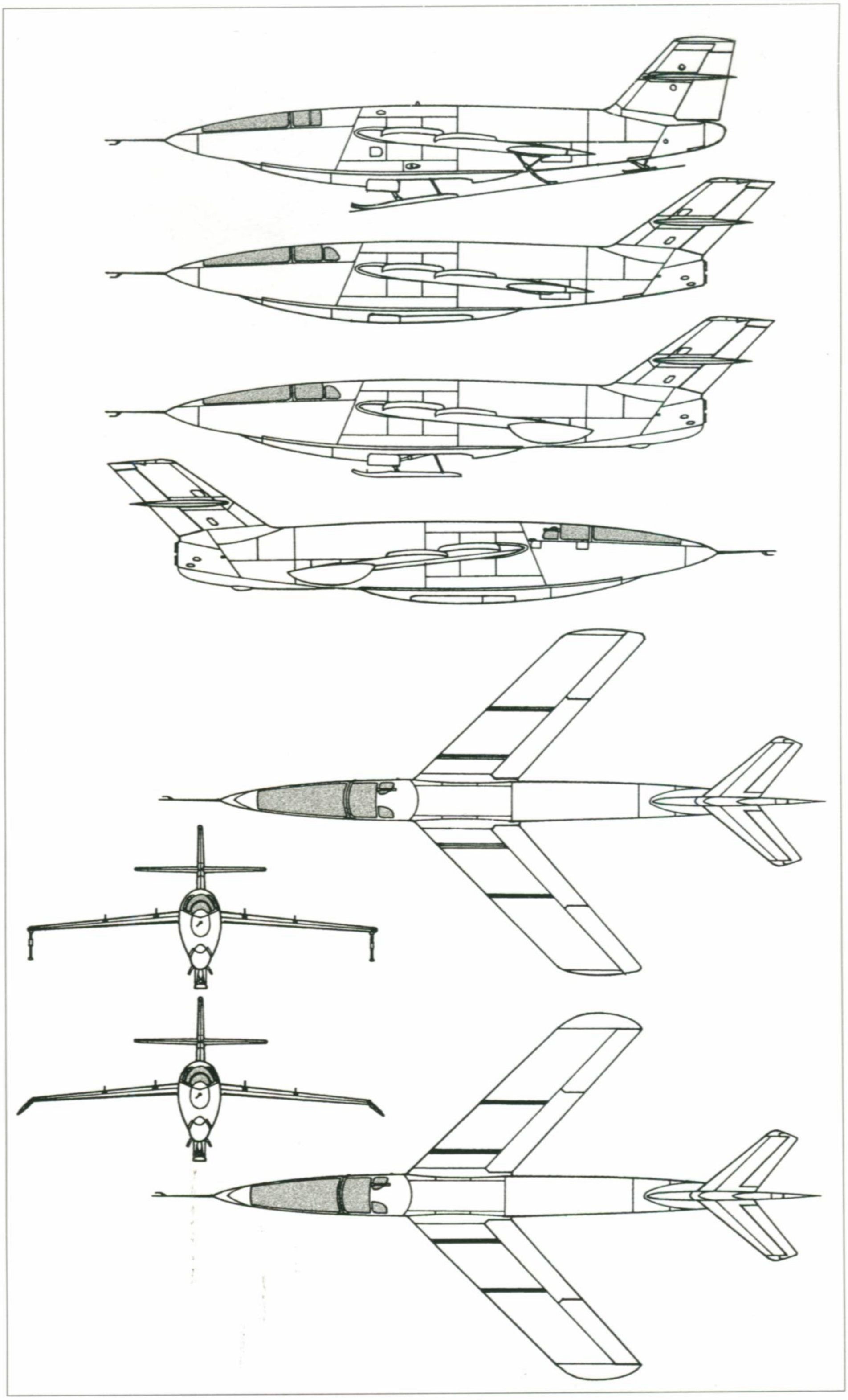
Type: Single-seat experimental aircraft. The airframe was of all-metal construction.

Fuselage: Monocoque stressed-skin structure of elliptical cross-section which gradually changed to oval at the edge of the rocket motor nozzles. The fuselage had a break point at frame 14 which permitted the rear fuselage to be detached for installing the propellant tanks and for other purposes.

The entire *forward fuselage* was occupied by the cockpit equipped with an ejection seat; the cockpit and its canopy turned out to be unusually long because the pilot was seated in a reclined position (feet first). This helped reduce the fuselage cross-section and hence reduce drag. The cockpit canopy blended into the fuselage contours; the hinged forward section opened to starboard. When the aircraft was suspended under a 'mother ship', it was possible to heat the cockpit with warm air fed via a flexible hose from the 'mother ship'. Silica gel cartridges were provided to demist the cockpit glazing. The port side of the canopy incorporated a direct vision window which was opened during the landing approach.

The *centre fuselage* housed integral fuel and oxidiser tanks made of stainless steel, with corrosion-resistant coatings inside. Airbrakes were provided on the fuselage sides aft of the wings; the *aft fuselage* housed the rocket motor. The fuselage length was 9.92 m (32 ft 6½ in), the structural weight was 225 kg (496 lb).

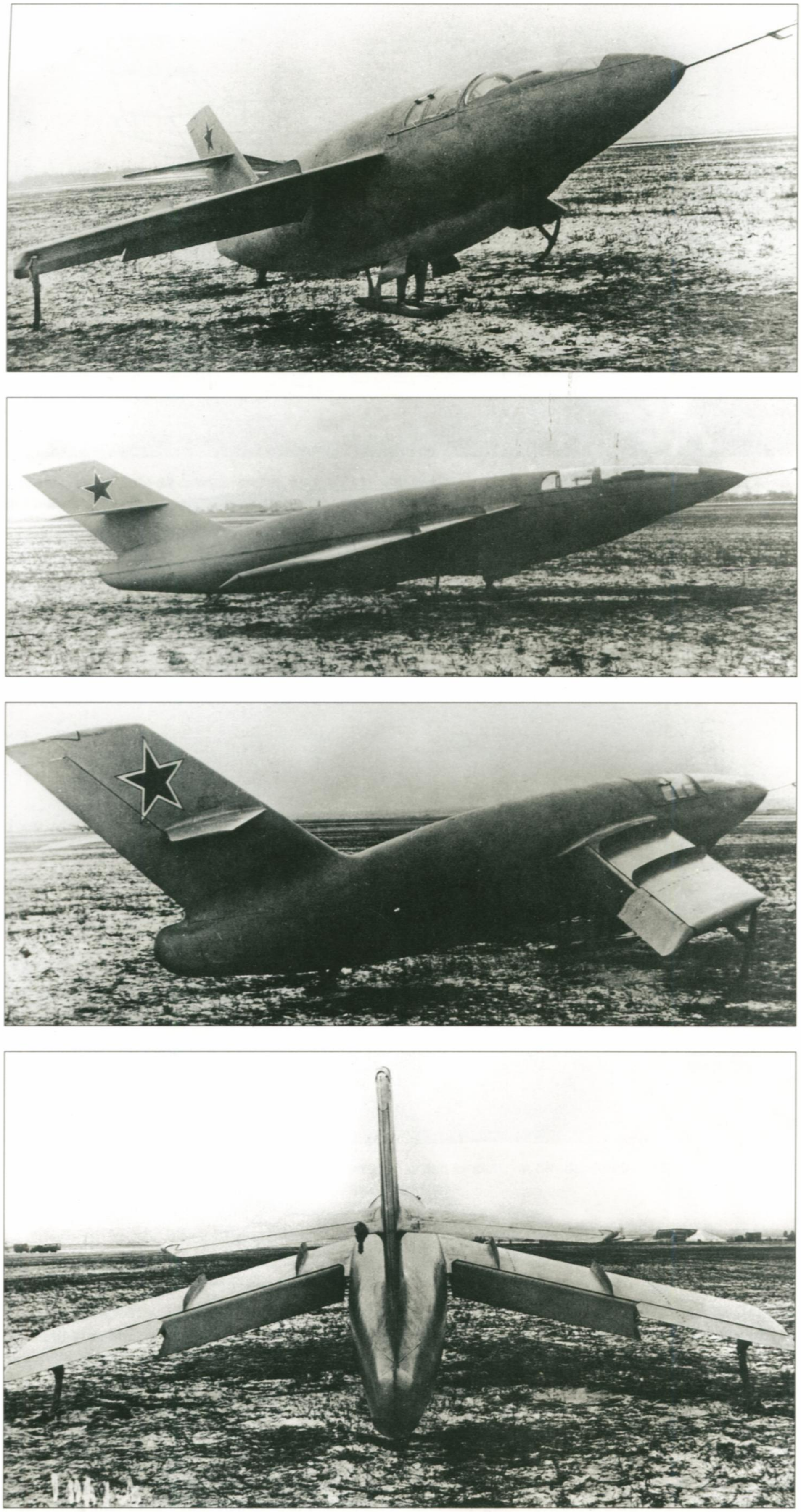
Wings: Cantilever mid-set wings of integral two-spar construction; sweepback at quarter chord 45°, leading-edge sweep 47°30', anhedral 5°, incidence +2°. The wings had a span of 6.4 m (21 ft 0 in) and an area of 11.315 m^2 (121.8 sq ft). The wings' structural weight was 320 kg (705 lb). TsAGI 12045 *bis* airfoils were utilised at the root, with TsAGI P2 (2M) airfoils at the tips. The wings were equipped with flaps occupying more than 50% of the span, with ailerons outboard of them. Two boundary layer fences were installed on the upper surface of each wing panel to prevent an early onset of tip stall. To enable the study of the pressure distribution on the wings at high speeds, the starboard wing panel was vented along three sections.



Top to bottom: The '5-1'; the '5-2' as originally flown; two views of the '5-2' with 'flippers' added to the wingtips; upper and front views of the '5-2' as originally built (with outrigger skids); ditto, with 'flippers'.

Tail Unit: Cruciform swept-back tail surfaces; the stabilisers had variable incidence and a span of 2.4 m (7 ft 10½ in). Should the elevator lose its efficiency during flights at high speeds, the pilot had the option of controlling the aircraft with the help of the stabiliser which could be linked to the control stick. The fin had a trapezoidal planform.

Landing Gear: Since the aircraft was to be air- launched from a 'mother ship', it was provided with a simplified landing gear. The latter comprised a retractable main skid, a small tailskid and two wingtip bows (or, later, outrigger skids). The landing gear track measured between the wingtip bows/outrigger skids was 6.00 m (19 ft 8 in). The undercar-



Four views of the second prototype B-5 ('-2') as originally flown with retractable outrigger skids and tailskid. Note the nose-up ground attitude and the lowered flaps occupying most of the span.

Above: Test pilot Gheorgiy M. Shiyanov, Hero of the Soviet Union, who flew the improved second prototype of the '5'.

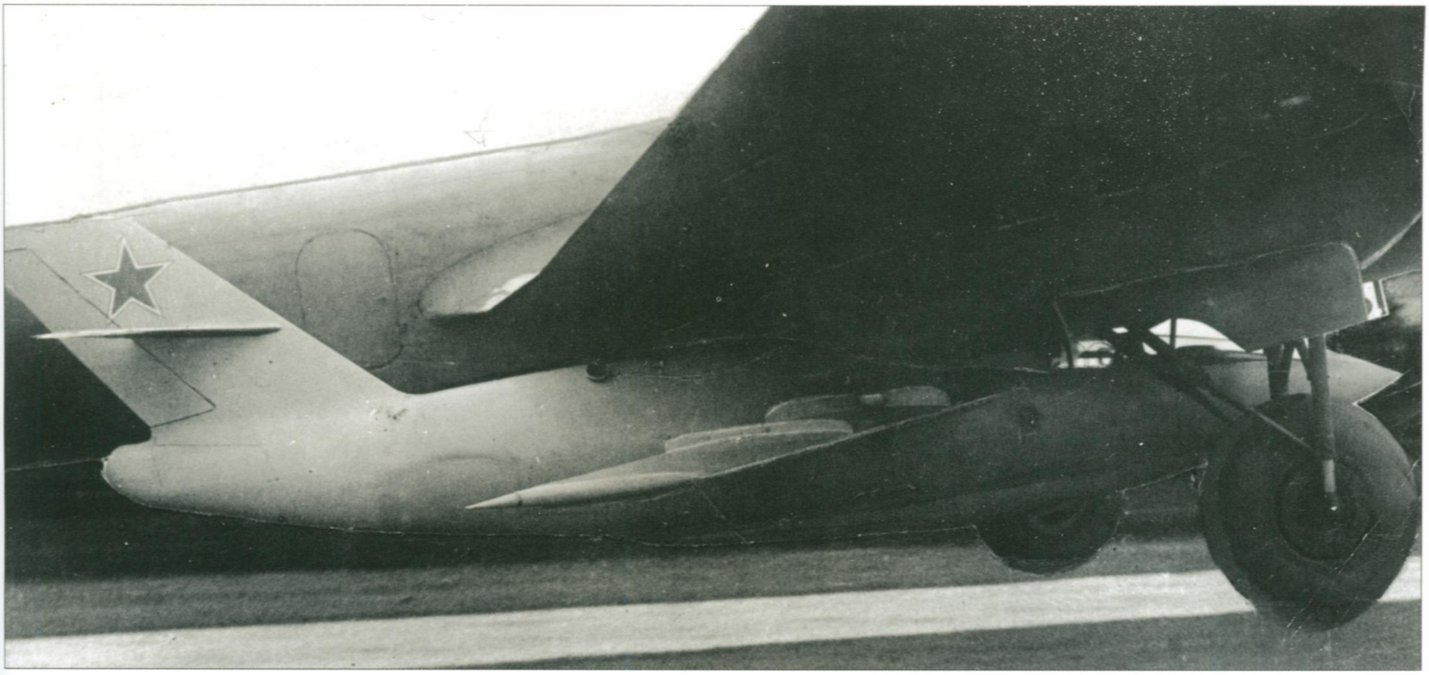
riage had a designated service life of five to seven landings. In the course of the testing the installation of the landing skid was altered in such a way that the aircraft retained its flight attitude after the touch-down. This made it possible to eliminate the tailskid.

Powerplant: One RD-2M3VF twin-chamber liquid-fuel rocket motor housed in the rear fuselage; maximum thrust 1,610 kgp (3,550 lbst) at sea level and 2,000 kgp (4,410 lbst) at altitudes above 8,000 m (26,240 ft). The amount of propellants (kerosene and nitric acid) and hydrogen peroxide (for feeding the turbopump unit) was designed to ensure two minutes' operation of the rocket motor at full thrust.

Control System: The control system used rigid linkages to all control surfaces and incorporated some novel features that were unusual for that time. The system incorporated irreversible hydraulic actuators that could be switched on at any moment of the flight.

'7' Experimental Aircraft

In the late 1940s the design bureau led by Matus R. Bisnovat developed one more rocket-propelled aircraft known as *izdeliye* '7' (or B-7). The aircraft, as it were, pre-empted the configuration of the future radio-controlled unmanned aerial vehicles and air-to-surface missiles which gained wide use many years later. The 'seven' was flown by LII test pilot Amet-Khan Sultan.



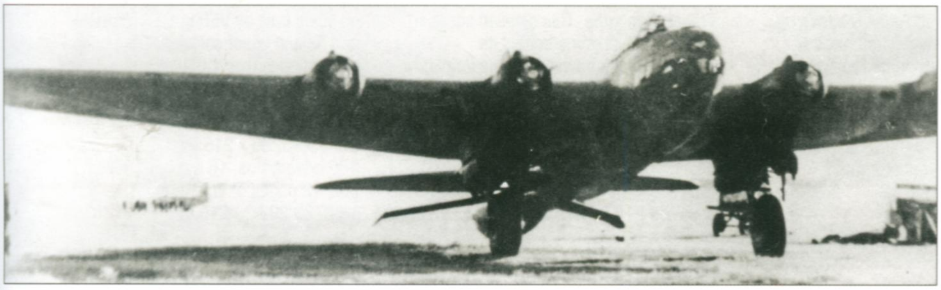
Above and left: The Pe-8 carrier aircraft prepares to take off with the '5-2' aircraft attached.

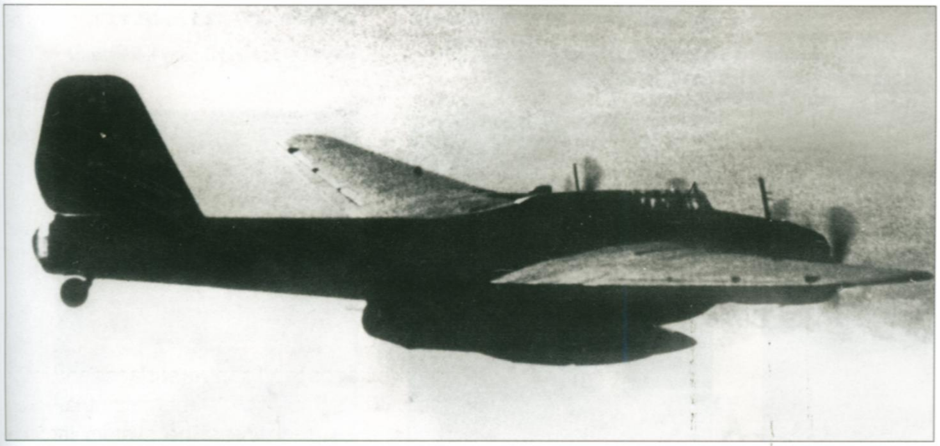
Below left: An air-to-air of the Pe-8 'mother ship' carrying the '5-2'.

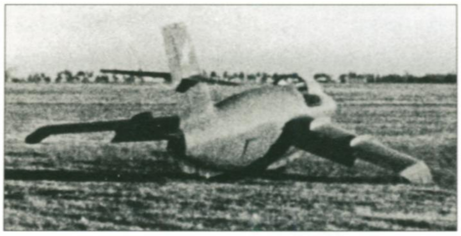
Below: The second prototype in its ultimate configuration with canted wingtips ('flippers'). Note the open cockpit canopy.

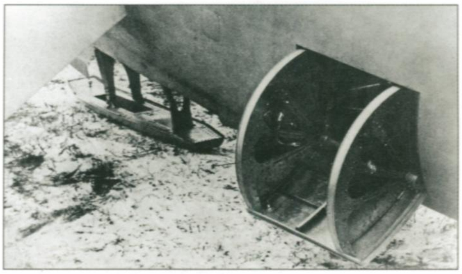
Centre: The fully open port airbrake.

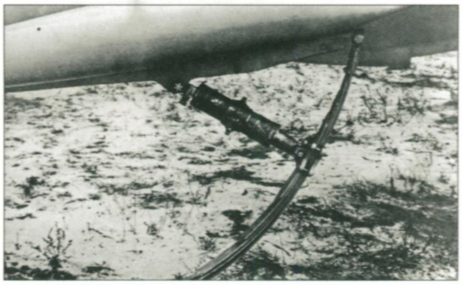
Bottom: The starboard outrigger skid with its shock absorber.











Specifications of the '5' (B-5)

Fuselage length:	
'5-1'	9.92 m (32 ft 6½ in)
'5-2' after modifications (less pitot)	11.2 m (36 ft 9 in)
Wing span:	
'5-1'	6.40 m (21 ft 0 in)
'5-2' with 'flippers'	6.60 m (21 ft 8 in)
Wing area, m² (sq ft)	11.315/11.18 (121.66/120.21)
Empty weight, kg (lb)	883 (1,947)
Maximum all-up weight, kg (lb)	3,184 (7,020)
Maximum design speed, km/h (mph)	1,200 (746)
Landing speed, km/h (mph)	153-160 (95-99)

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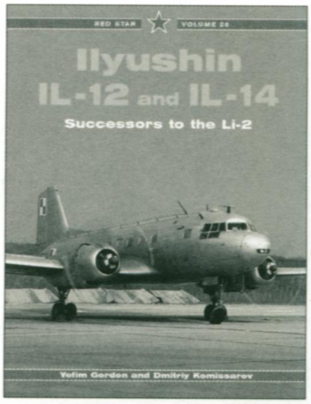

Designed to supersede the Li-2, the 29-seat IL-12 airliner entered Aeroflot service in 1948. Some 600 were built for Aeroflot and the Soviet armed forces. The improved IL-14 entered production in 1953, the type was exported to China, Bulgaria, Romania and Poland as well as being built by VEB in East Germany and Asia in Czechoslovakia. The total production of over 1,000 aircraft included 203 Avia 14s and Avia 14 Supers – the latter being a pressurised development.

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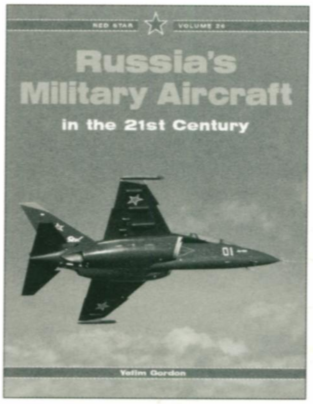

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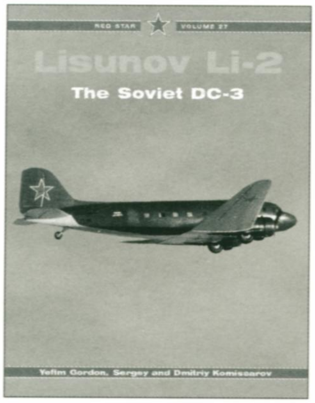

When they bought a manufacturing licence for the DC-3 in 1936, Soviet decision makers had no way of knowing the place the Douglas airliner would come to occupy in aviation's hall of fame. Adapted to employ Russian engines and materials, the DC-3 entered production as the PS-84; later redesignated Li-2. This addition to the series explores what is probably the least-known aspect of the history of one of the world's best-known airliners.

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